STATE OF MARYLAND
BOARD OF NATURAL RESOURCES
MARYLAND GEOLOGICAL SURVEY
KENNETH N. WEAVER, *Director*

BULLETIN 28

Copper, Zinc, Lead, Iron, Cobalt, and Barite Deposits in the Piedmont Upland of Maryland

by

ALLEN V. HEYL AND NANCY C. PEARRE

Published by Permission of The Director, U.S. Geological Survey

Baltimore, Maryland
1965

PREFACE

This report by Dr. Allen V. Heyl and Miss Nancy C. Pearre, geologists for the U. S. Geological Survey, represents the culmination of an effort to gather into one volume all that is known of the copper and related mineral deposits of the Piedmont upland of Maryland.

Because the last operating copper mine was closed down some 47 years ago, much of the information contained in this report had to be extracted from old published reports on the deposits. The authors were not content to rely only upon the most obvious sources of information in State and Federal scientific publications and scientific journals, but rather gleaned additional valuable information from old newspaper accounts, and records and prospectuses of the companies which operated the mines. A history of copper mining in Maryland was published by Miss Pearre in the Maryland Historical Magazine in 1964.

In addition to literature research the authors visited the sites of all the known mines and were able to gather additional valuable data on the types of operations and indirect evidence on the amount of ore produced. The geological setting, types of ore and mode of emplacement are discussed for the three mineralized districts.

This report represents a valuable addition to the publications of the Maryland Geological Survey in its continuing effort to provide the most up to date geological data on the State. Although it is unlikely that Maryland will become a significant producer of metallic ores in the foreseeable future, the data presented in this volume will prove invaluable for a mining company interested in exploration within the State. As the present large deposits of copper ore in the Western United States become depleted, and as exploration techniques become more refined, it is conceivable that the potential deposits in Maryland, which are located in close proximity to large refineries in the Baltimore area, will be more closely examined.

The report also illustrates the need for detailed geologic studies at the time of active operation of a mine. No detailed geologic studies were made of the mines while they were in operation so that our information today is incomplete and must be gleaned from such indirect evidence as material left in the mine dump, old mine prospectuses, and general geologic reports.

This need for detailed geologic data can be applied today to various construction exposures. If the road cut or building excavation is not examined during the construction phase, the valuable data is lost because the exposure will be either landscaped, grassed over or covered with concrete.

KENNETH N. WEAVER
Director

Contents

List of Illustrations

Tables

Copper, Zinc, Lead, Iron, Cobalt, and Barite Deposits in the Piedmont Upland of Maryland

by

Allen V. Heyl and Nancy C. Pearre

ABSTRACT

Three copper districts—from west to east, respectively, the Linganore, Sykesville, and Bare Hills—lie within the Piedmont upland of Maryland, which is 20 to 40 miles wide. Their aggregate output is not known, but incomplete production statistics indicate not less than 10,000 tons of metallic copper, worth more than 3 million dollars. Copper mining in Maryland began about 1750 and continued at intervals thereafter until 1918. Several of the early mines were large for their time.

In addition to copper, the Linganore district has produced zinc, lead, silver, and gold, and the Sykesville district has produced iron. Cobalt is a constituent of the Sykesville ores, but it has never been recovered commercially.

The bedrock of the Piedmont upland in Maryland increases in metamorphic grade eastward, from low-grade greenschist facies in the Linganore district to intermediate-grade amphibolite facies in the Bare Hills district. Similarly, the ore deposits grade from mesothermal in the Linganore district to hypothermal in the Bare Hills district.

The Linganore district, in Frederick and Carroll Counties, is in the western part of the Piedmont upland. The main primary minerals that have been of commercial value are bornite, chalcopyrite, chalcocite, argentiferous galena, sphalerite, and barite. Most of the minerals are in fine-grained replacement bodies and breccia ore bodies in marble, commonly near the contact between marble and metavolcanic rocks or phyllite. Where mineralized, the marble is brecciated and manganiferous. A few ore bodies are in veins.

The Sykesville district, mostly in Carroll County extending into westernmost Baltimore County, is in the central part of the Piedmont upland in a transitional belt of schists and gneisses of both the greenschist and amphibolite facies. Some of the rocks show retrogressive metamorphism. The deposits are in veins, in faults, and in lenticular bodies of chlorite-amphibole schist. Chalcopyrite, bornite, magnetite, hematite, sphalerite, and carrollite are the main ore minerals. Quartz and actinolite are common gangue minerals.

The Bare Hills district in the northern suburbs of Baltimore is in the eastern part of the Piedmont upland. Lenticular veins of magnetite and chalcopyrite, with a little bornite, are in gneissic rocks of the amphibolite facies. Coarse-grained silicates such as hornblende, cummingtonite, and anthophyllite are gangue minerals in the veins and in adjacent wall rocks.

INTRODUCTION

Copper has been mined in the Piedmont upland of Maryland in the Linganore, Sykesville, and Bare Hills districts (fig. 1). Other metals either were produced or occur with copper in potentially economic quantities. In the Linganore district, lead, zinc, and barite were mined; silver and a little gold were recovered as byproducts of copper mining. Small deposits of hematite have been reported. In the Sykesville district, magnetite and hematite were produced, and the copper-iron ores contain sufficient cobalt to be of potential commercial interest. Siliceous magnetite ore composes a large part of the Bare Hills deposits, but no production of it is reported.

The Linganore district, in Frederick and Carroll Counties, includes the Liberty, New London, Dolly Hyde, Repp, Roop, and Cox mines, the Mountain View lead mine, the Unionville zinc mine, the Hammond (Pittinger), Hines, Eiler, and Israel Creek prospects, and the Sauble barite prospect. The Springfield, Carroll, Mineral Hill, and Patapsco mines and the Beasman and Monroe prospects constitute the Sykesville district in eastern Carroll County, and the small Bare Hills district in Baltimore County contains the Bare Hills or Vernon mine and some nearby prospects. Several of the mines were large for their time; they ranked high in importance before the Lake Superior copper mines were opened in the 1840's. Extensive workings, particularly at the Liberty and Mineral Hill mines, still attest the vigor and enthusiasm with which they once were operated.

SCOPE OF REPORT

This report is a compilation of available information on the copper-iron and copper-lead-zinc deposits of the Piedmont upland in Maryland. It is based mostly on extensive library research that was done intermittently between 1952 and 1958. Compilation was supported where necessary and possible by field examination of the districts, by some detailed mine and geologic mapping in selected parts, and by petrologic and mineralogic studies.

PREVIOUS WORK

The areal geology of Frederick County and western Carroll County, including the Linganore district, was mapped by A. I. Jonas and G. W.

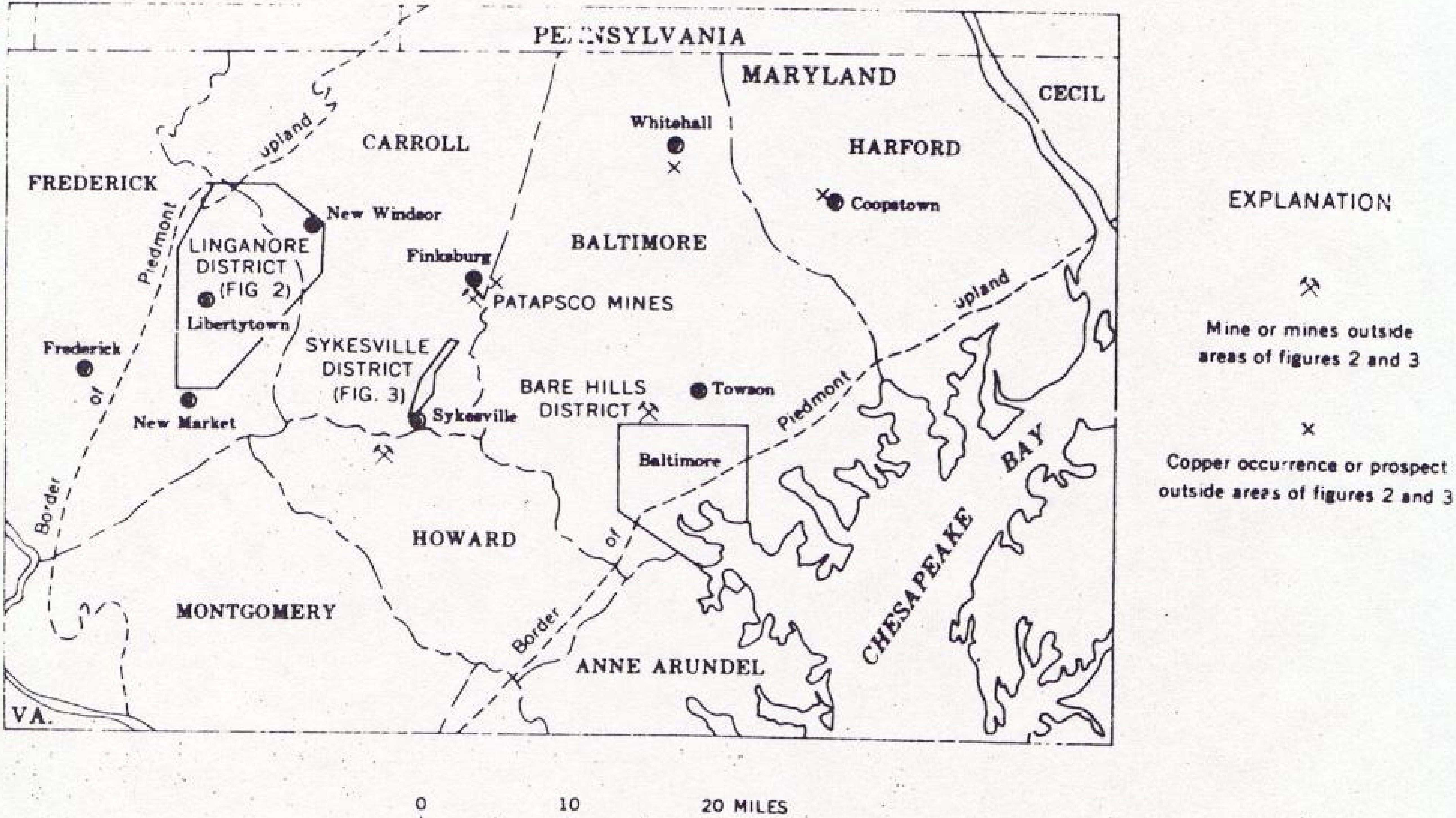


Figure 1. Index map showing copper mining districts in the Piedmont upland in Maryland

FIGURE 1. Index map, showing copper mining districts in the Piedmont upland in Maryland.

Stose (1938) and described by them in some detail (Stose and Stose, 1946). The geology of eastern Carroll County, including the Sykesville district, was mapped by Jonas (1928); the southern part of the district was remapped by the writers (fig. 5). Howard County at the southern edge of the Sykesville district was mapped by Cloos and Broedel (1940). Baltimore County, including the Bare Hills district, was mapped by Jonas, Knopf, and others (1925).

A rather comprehensive geologic and petrologic study of the Linganore and Sykesville deposits was made by Overbeck (1916), whose work has been used in parts of this report. Unfortunately, no detailed geologic study was made while the mines were active, and information about the deposits underground can be obtained only from examination of material left on the mine dumps, from old mine prospectuses, and from general geologic reports.

In 1964 a comprehensive report on the geology of Howard and Montgomery Counties (Maryland Geological Survey, 1964) was published. This report contains much valuable information on all phases of the geology of these two counties, much of which is applicable to contiguous parts of the Piedmont upland. Of particular interest is the pages in this book by C. A. Hopson (1964) in which the geology, petrology and geologic history of the crystalline rocks are described.

ACKNOWLEDGMENTS

Information from a manuscript record book of Isaac Tyson, Jr., is published with the kind permission of the Maryland Historical Society, Baltimore, Md. Files of the Frederick Daily News were made available by the C. Burr Artz Library in Frederick, Md. The writers were aided in their field work by Maurice R. Brock of the U. S. Geological Survey, and they are indebted to G. H. Espenshade, also of the U. S. Geological Survey, for information from his reconnaissance work in the Maryland copper districts in 1942. Mrs. William H. Griffin 3d, Westminster, Md., supplied information about the Liberty mines, including a blueprint of the mine workings, which is used, with her permission, in figure 3. Thanks are also due to Mr. Charles Cashour and Mr. Charles Tregoning of New London, Md.; Mr. Paul E. Young of Unionville, Md.; Mr. Thomas Fleiter and son, Gamber, Md.; Deane F. Kent of the American Smelting and Refining Co.; and Paul Herbert, Assistant Manager of Tri-State Zinc Co.

Copper mining in Maryland began about 1750 and continued at intervals thereafter until 1918. A detailed history of the copper mines has been publi hed by Pearre (1964).

The Mineral Hill and Liberty mines (figs. 5, 2) and a third mine (probably either one of the Cox mines or the Repp mine) were productive prior to the Revolutionary War, but apparently were no longer being worked when the war ended. About 1833, or perhaps earlier, concentrates from copper-rich soil dug at the Liberty mine and elsewhere near Libertytown were used to manufacture copper sulfate in Baltimore. More than 50,000 pounds of copper sulfate was produced annually; most of it was exported (Ducatel and Alexander, 1834, p. 23, map).

Mining for copper other than from the residual soils was renewed in 1837 with the opening of the New London mine in the Linganore district, and from then until 1890 very few years passed during which there was not at least one active copper mine in Maryland. In 1844 the Bare Hills mine was begun, and in 1849 the mines in the Sykesville district were opened, at first for iron but later for copper. A temporary lull in activity about 1859 was followed by a period of renewed effort, particularly about 1864, when the price of copper reached a high of 47 cents per pound. Unfortunately, details about the mines during this "boom" period are lacking. Aside from the census reports of 1870 and 1880, little specific information is available until the beginning of the twentieth century.

Between 1900 and 1918 activity was confined mostly to the Linganore district, where a succession of small companies produced copper by reworking the old mill tailings at the Liberty mine and by underground work at the New London mine. The Springfield mine in the Sykesville district was worked about 1916 as an open cut, to produce specular hematite-quartz ore for the manufacture of ferro-silicon. Several sporadic attempts shortly after 1900 to reactivate the Bare Hill mines were unsuccessful. Prospecting has been renewed at intervals in recent years in the Linganore district.

PRODUCTION AND GRADE

Accurate records of total production from the copper mines in Maryland are nonexistent. Nearly complete estimates have been published only for the Bare Hills mine, which reportedly produced more than 5,800 tons of metallic copper valued at $1,755,000, and for the Dolly Hyde mine, to which is attributed a total of 58 short tons of metallic copper valued at $23,000. A reasonable estimate for the Liberty mine is 3,000 tons* of metallic copper—close to $1,000,000 in value. At least one of the others—the Mineral Hill mine—was a large producer, probably comparable to the Bare Hills mine, and at least three others—the Springfield, New London, and Patapsco—were certainly very much larger producers than the Dolly Hyde. The sum of all the fragments of production recorded, including the estimates for the Bare Hills, Dolly Hyde, and Liberty mines, and very incomplete figures for the Mineral Hill, Springfield, New London, and Patapsco mines, is about 10,000 tons of metallic copper, the value of which is estimated as over $3,000,000. This is probably little more than half of Maryland's total copper production.

Several mines in the Sykesville district produced iron ore, but the only published record is of 218 tons of magnetite ore (137 tons metallic iron) from the Mineral Hill mine in 1880 (Pumpelly, 1886a, p. 24). The large size of the open cut made at the Springfield mine in 1916 indicates that several thousand tons of specular hematite-quartz rock were removed for the manufacture of ferro-silicon.

The only record of zinc production is from the Unionville mine in 1880, when 672 tons of ore valued at $7,200 was mined (Pumpelly, 1886b, p. xxxi, 804). Zinc was worth 5.5 cents per pound in 1880, so the ore (probably oxidized zinc ore) apparently averaged almost 10 percent zinc. Additional zinc may have been recovered from the Cox group of mines. Some lead was produced at the Cox-Mountain View mines and possibly at the Dolly Hyde mine.

Between 1905 and 1917 copper mines in the Linganore district produced as byproducts 2,393 fine troy ounces of silver, valued at $1,724, and 3.43 ounces of gold, valued at $71. There is no record of the amount of silver recovered during the earlier years, when the Dolly Hyde mine produced argentiferous ore. Barite mined on the Sauble property probably never was shipped.

Table 1 summarizes the available copper production data and gives estimates made by the writers to indicate very roughly the amount of total production from some of the mines. All figures have been con-

*Based on estimated 100,000 tons of ore mined from underground workings before 1900, and a probable average grade of about 3 percent copper.

TABLE 1. Production of copper from mines in Maryland.

Mines in approx. order of size	District	Tons of metallic copper (based on available specific data)	Approx. value (based on available specific data)	Approx. No. of active years not included	Estimate of total production[1] tons metallic Cu	Products other than copper
Liberty mine	Linganore	>3,000	$1,000,000	...	>3,000	silver
Bare Hills mine	Bare Hills	5,850	1,755,000	7	5,000-6,000	...
Mineral Hill	Sykesville	> 35½	>15 000	60	5,000	iron
Springfield mine	Sykesville	> 530	>230,000	10	2,000	iron
New London mine	Linganore	> 222	> 89,000	40	1,000	silver, gold
Patapsco mines	Sykesville	> 40	> 13,000	12	500	iron, cobalt[4]
Repp mine	Linganore	...	...	all	probably fairly small	...
Dolly Hyde mine	Linganore	58	23,000	none	58	silver, lead[5]
Cox-Mountain View mines	Linganore	...	...	all	probably fairly small	lead, zinc[5]
Carroll mine	Sykesville	several tons	...	...	3-5	iron
Unionville zinc mine	Linganore	[2]	...	...	0.5 ton	zinc
Hammond-Hines prospects	Linganore	[3]	...	all	small	...
Beasman prospect	Sykesville	no copper	..	...	no copper	iron (?)
Monroe prospect	Sykesville	no copper	...	...	no copper	iron (?)
Roop mine	Linganore	very small quantity	...	...	at most, 0.5 ton	zinc (?)[6]
TOTALS		>9,735.5	>$3,125,000		>17,562	

[1]Estimates by the writers based on available historical data, reported size of underground workings, number of active years for which no information is available, reported grade of ore, and present appearance of mine. Indicates order of magnitude only.
[2]Two tons of copper, ore, grade not known, in 1879.
[3]Some production of copper-bearing soil for manufacture of copper sulfate.
[4]Production attempted but never successfully.
[5]Probably produced, but no available records.
[6]Several hundred tons of oxidized zinc ore were shipped to the Lehigh Zinc Co. in 1879 from an unspecified property which may have been the Roop mine rather than the Unionville zinc mine or the Cox group of mines (Engineering and Mining Journal, 1879, p. 449).

verted to short tons of metallic copper to facilitate comparison. The information is documented, and grade of raw ore is discussed, in the paragraphs that follow the table.

LINGANORE DISTRICT

The total production from the Linganore district is considerably more than 3,000 tons of metallic copper and probably considerably more than 4,000 tons; at least 2,400 ounces of silver, 3½ ounces of gold, and 67 tons of metallic zinc. Lead production is not known.

Liberty mine.—Production from the underground workings shown on figure 3 is estimated as about 100,000 tons of ore. Average grade of

TABLE 2. Copper production from the Liberty mine, Linganore district.

Years of activity (approx.)	Metallic copper (short tons)	Value (approx.)	Source
1750–1764	Some ore smelted (?)		
1765–1783 1830–1834 1838–1840	> 200	48,000	Ducatel (1841, p. 46); Ducatel and Alexander (1834, p. 23)
1864–1869	Unknown but probably large.		
1870	153	65,000	U. S. 9th Census (p. 762)
1871–1874	Unknown but large.		
1875–1885	Intermittent production.		
1886–1899	Several carloads of ore shipped.		Engineering and Mining Journal (1899, p. 213)
1900–1903	Development work, probably no production.		
1905	A little obtained from reworking mine dumps.		Data provided by U. S. Bureau of Mines
1907	[1] 7.6	3,040	Data provided by U. S. Bureau of Mines
1916–1917	[2] 122.4	64,216	Data provided by U. S. Bureau of Mines
TOTAL	> 483.0	$180,256	

[1] Obtained from 2,500 tons of ore during experimental work.
[2] Obtained by reworking 13,500 tons of old tailings that ran 0.6% to 3% copper and by smelting 10 tons of ore that contained 19% copper. In addition the ore and concentrates yielded 973 ounces of silver valued at $737 and 2.09 ounces of gold valued at $43.

the Liberty ore was reported in 1906 as 2.16 percent copper, 4.7 ounces of silver, and $1.80 in gold per ton (Stevens, 1906, p. 1035). The grade was probably considerably better than this in parts of the mine, so that 3,000 tons of metallic copper, or close to $1,000,000 worth, is not an unreasonable rough estimate of total production from the mine.

Table 2 of definite information about the production of the Liberty mine is published with permission of the property owners.

New London mine.—Recorded production data are presented in Table 3. Grade of hand-sorted ore produced during the earlier operations was 10 to 11 percent copper, according to one report (Butler and McCaskey, 1915, p. 286), but averaged 20 percent copper according to another (Ducatel, 1841, p. 46). Average copper content was 3.6 percent on the 200-foot level and 4.9 percent at a depth of 210 feet (Butler and McCaskey, 1915, p. 286). In 1910 the Linganore Copper Co. estimated that

TABLE 3. Copper production from the New London mine, Linganore districts[1]

Years of activity (approx.)	Metallic copper (short tons)	Value (approx.)	Source
1837-1840	40	$ 9,600	Ducatel (1841, p. 46)
1840-1853	Unknown. Reportedly very successful.		
1860-1861	Development work, probably no production.		
1864-1870's	Intermittent; no production in 1870.		
1884-1888	Reportedly successful.		
1903-1904	Open; no ore mined.		
1909	1.2	320	Data provided by U. S. Bureau of Mines
1911-1912	71.6	22,735	do.
1914	6.1	1,629	do.
1916-1917	102.7	54,424	do.
TOTAL	>221.6	$88,708	

[1]Published with permission of owner

the ore averaged 3 percent copper and carried 16 ounces of silver per ton, with a trace of gold (Stevens, 1910, p. 1075-1076), an estimate that was too high when compared to actual grade produced. During the four years 1911-1912 and 1916-1917, 18,390 tons of raw ore that contained 0.54 to 2.2 percent copper was concentrated in a mill on the property; 1.77 ounces of gold valued at $38 and 1,327 ounces of silver valued at $920 were recovered as byproducts. Concentrates reportedly averaged about 1 ounce of silver per ton and about 24 percent copper (Singewald, 1946, p. 156), although the 1917 shipments contained as much as 44 percent copper.

Dolly Hyde mine.—Total production was reported as more than 58 short tons of metallic copper by Dieffenbach (1858, p. 67). In 1840 Richard Coale produced 60 to 80 tons of washed concentrates that sold for $60 a ton. Concentrates were estimated to run 20-30 percent copper. An assay report made by the Baltimore copper furnaces (Jackson, 1853a, p. 478) listed 86 tons of ore that ranged from 19 to 26 percent copper

(1842-1853) and 127 tons of "black dirt" than ranged from 7 to 16 percent copper (1847-1853).

SYKESVILLE DISTRICT

The reported production is a little more than 600 tons of metallic copper; the writers' rough estimate of total production is about 7,500 tons. All the mines produced iron as well as copper.

Springfield mine.—The known production of the Springfield mine is given in Table 4.

TABLE 4. Copper production from the Springfield mine, Sykesville district.

...ar[1]	Ore (tons)	Percent copper (average)	Source
1852 1854	150	....	Whitney (1854, p. 319)
1854-1856	Not known.	....	....
1857	300	16	Piggot (1858, p. 264)
1858	475	13	Tyson (1862, p. 67)
1859	684	do.	do.
1860	738	do.	do.
1861	1,728	do.	do.
1862 1869	Not known; increase expected to continue.	....	Tyson (1862, p. 68)
TOTAL	4,075 tons		

[1] 1857-1861 figures are for years beginning in April.

At 13 percent copper, 4,075 tons of ore represents 530 tons of metallic copper. This is probably considerably less than half of the total copper production from the mine. The ore brought $50 to $60 a ton (Tyson, 1862, p. 67). From 1849 to 1852 and again in 1880 and 1916, the mine produced iron ore.

Carroll mine.—In 1864 several tons of copper ore that was reported to contain 25 percent copper were mined from a new shaft during development work (Martin and Vivian, 1865, p. 8). The sparsity of copper on the dumps suggests that very little more was produced than the few tons. The dump from the "copper shaft" is very small.

Mineral Hill mine.—Very little specific production information is available. The size of the pre-Revolution workings—large for their time—suggests that a notable quantity of copper was produced from 1749 to about 1776. The mine operated almost continuously between 1849 and 1890, and for many years, particularly before 1864, production was large. At times as many as 100 men are reported to have been working there. The size of the known workings and remaining dumps suggests that the mine was roughly comparable in size to the Liberty and Bare Hills mines.

Whitney (1854, p. 319) reports that by 1854, 100 tons of 15 to 20 percent copper ore had been stoped out, and an additional 15 to 20 tons had been mined during development work (more than 17 tons of metallic copper, 1849 to 1853). The ninth census credits the mine with $6,500 worth of copper for the year 1870; at the price of copper quoted in that year (21.2 cents per pound), this represents about 15 tons of metal. The tenth census (Pumpelly, 1886a, p. 24, 28; 1886b, p. 798-799) reports that in 1880 7,058 pounds (3½ tons) of copper ingots, valued at $1,200 were produced from 82 tons of ore (which averaged a little more than 4 percent copper); and 218 tons of magnetite (which contained 137 tons metallic iron).

Patapsco mines.—Total production is not known. In 1851 the company reported monthly receipts totalling almost $10,000 for 163 tons of ore, the average grade of which was 20 percent copper (Remington, 1852, p. 11). Previous sales during development work and subsequent sales early in 1852 increased the total ore shipped to at least 200 tons. From the size of stopes mapped in May 1852, the authors estimate that 2,700 tons of ore and rock had been mined at the Wildesen mine and 1,050 tons of ore and rock at the Orchard mine up to that date. The mines were operated until 1858 and again from 1860 to 1865, so these figures are only fragmentary. Iron ore was the main product in the early 1880's.

BARE HILLS DISTRICT

A Doctor Lehmann of Baltimore, who supervised the sampling and assaying of ore from the Bare Hills copper mine from 1866 to 1887, roughly estimated production after the records of his office and the copper company were destroyed by fire (Weed, 1911, p. 65). According to him, yearly shipments before 1866 were 2,000 to 2,500 tons of ore that was 15 to 20 percent copper. From 1866 to 1876 the annual total was 800 to 1,200 tons of large size cobbed ore averaging 18 percent copper and 1,000 to 1,500 tons of fine-grained "hutched ore" or concentrates. Shipments gradually decreased from 1866 to 1887, so that during the period 1883 to 1886 only about 50 tons a month of cobbed ore averaging 19 percent copper were shipped. In 1880 output of the mine was 17 tons of ore from which 1,275 pounds of copper was produced, indicating that grade of the ore was 3 to 4 percent (Pumpelly, 1886b, p. 798-799).

Averaging these figures, Weed (1911, p. 65) reports total output from 1864 to 1887 as about 32,500 tons of ore that contained 18 percent copper. The total value of this ore, at $54 a ton (15 cents per pound of copper), would be $1,755,000.

This estimate of total production may, however, be too large. Moore (1935) quotes the following figures for ore mined during the period from 1863 to 1865: 1863–432 long tons (of 2,352 pounds), 11.11 percent copper, value $21,558; 1864–700 tons,* value about $54,300; 1865–about 75 tons* a month (or 900 tons*). According to this, production before 1866 was considerably less than Dr. Lehmann's estimate of yearly shipments for the same period (2,000 to 2,500 tons of 15 to 20 percent ore). Dr. Dr. Lehmann's estimate presumably does not include the earliest years between 1839 and 1850. However, it does include years when the mine was probably not producing at all. A flood in 1868 stopped work for a while–perhaps for several years, inasmuch as no production is reported in 1870 (the year of the ninth census).

*Long or short tons not specified.

The Piedmont upland, which extends northeastward from Alabama to New Jersey, is 20 to 40 miles wide in Maryland (fig. 1). It is characterized by rolling hills with gentle slopes, and maximum altitudes are about 1,000 feet above sea level. The Piedmont upland is underlain by highly crystalline Baltimore Gneiss of Precambrian age and by quartzite, schist, gneiss, marble, phyllite, and greenstone of Paleozoic (?) age. These rocks are intruded by granitic, gabbroic, and ultramafic rocks of Paleozoic age. The upland is bounded on the southeast by Cretaceous and Tertiary sediments of the Coastal Plain and on the northwest by early Paleozoic marble and crystalline limestone of the Frederick Valley and by unmetamorphosed conglomerate, sandstone, and shale of the Triassic lowlands.

The geology of the Piedmont upland in Maryland is described in detail by Stose and Stose (1946) and by Knopf and Jonas (1929), and in a recent report by The Maryland Geological Survey (1964). Information from these reports is used in the following brief descriptions of Rock units, Structure and Metamorphism, and in the more detailed descriptions of the geologic environment of each of the copper districts. For further details, the reader is referred to their reports and to the geologic maps of Frederick, Carroll, Howard, and Baltimore Counties, published by the Maryland Geological Survey (Jonas and Stose, 1938; Jonas, 1928; Cloos and Broedel, 1940; Jonas, Knopf, and others, 1925).

ROCK UNITS

Oldest of the crystalline rocks that constitute the Piedmont upland in Maryland is the Baltimore Gneiss of Precambrian age, which is exposed in several anticlines in the southeastern part of the upland. It is an injection complex that includes granitoid gneiss, injection gneiss, hornblende gneiss, altered aplite, and augen gneiss, representing a heterogeneous group of metamorphosed sedimentary rocks and granitic intrusions. These rocks were highly folded, metamorphosed, and eroded before younger rocks were deposited.

The Setters Formation, which rests unconformably on the Baltimore Gneiss, consists mainly of quartzite, schist, and gneiss. It is the basal unit of an extensive group of quartzites, marbles, schists, and gneisses, known as the Glenarm Series, the age of which has been a subject of prolonged controversy. The series includes, above the Setters Formation, a crystalline white marble called the Cockeysville Marble then a vast group of schists and gneisses of various metamorphic grades, the Wissahickon

Formation, and finally a series of metamorphosed schists, quartzites, and conglomerates known as the Peters Creek Formation as used by Hopson (1964).

The Peters Creek Formation as used by Hopson (1964) has been mapped in a belt that passes through the southern part of the Sykesville district, Finksburg, Whitehall, and the northern part of Harford County (fig. 1), roughly dividing the Piedmont upland in half. It occurs in a westward-dipping homocline (Hopson, 1964, p. 54-56) between a rather high metamorphic eastern facies of the Wissahickon (oligoclase-mica schist of the amphibolite facies) to the southeast and a lower metamorphic western facies (albite-chlorite schist of the greenschist facies) to the northwest. The schist and schistose quartzite of the Peters Creek Formation are also somewhat less metamorphosed; the formation grades northwestward into the albite-chlorite schist of the Wissahickon Formation.

The sequence of rocks in the western half of the upland differs considerably from that in the eastern half. Underlying the albite-chlorite schist of the Wissahickon Formation is a volcanic series that includes low-grade metamorphosed felsic and mafic lavas and tuffaceous slates in Frederick County. Clastic and pyroclastic quartzites are interbedded with and overlie these rocks. The volcanic series is infolded and interbedded with, and underlain by, the Wakefield Marble, which grades locally along strike into the Silver Run Limestone. Both formations were formerly mapped as Cockeysville Marble. Volcanic rocks and marble crop out in the Linganore district and northeastward across Carroll County from New Windsor to the Pennsylvania border (fig. 1).

The paraschists and paragneisses of the Piedmont upland are intruded by serpentinite, pyroxenite, peridotite, gabbro and metagabbro, and granitic rocks. Most of the southeastern border of the Piedmont upland shown in figure 1 consists of large masses of igneous rocks of different compositions. The Bare Hills district is in the northeastern corner of an extensive mass of gabbro and metagabbro, around the edge of which are smaller discrete bodies of serpentinite, pyroxenite, and peridotite. The northeastern end of a long belt of granite-appearing rocks—the Sykesville granite of Jonas (1928), now called the Sykesville Formation—crosses the southeastern corner of Carroll County just east of the Sykesville district (figs. 1, 5). Cloos and Cooke (1953) and Hopson (1964 p. 101-116) classify the Sykesville Formation as a metasedimentary rock formed from a submarine slide. The rock consists of a heterogeneous group of pebble and boulder-bearing arenaceous to pelitic metamorphic rocks, the groundmass of which resembles medium grained to weakly gneissic granite (Hopson, 1964, p. 103). Small bodies of mafic igneous rocks intrude both the Peters Creek Formation and the Wissahickon Formation. The exact age of the intrusives is not known. They are older than the regional folding and were deformed by it (Stose and Stose, 1946, p. 93).

STRUCTURE

The rocks of the Piedmont upland are closely folded; folds range from major structures to microscopic ones. Schistosity generally parallels bedding, and the rocks have closely spaced transverse cleavage, which is more pronounced in the northwestern part of the upland. These structures extend northeastward into Pennsylvania and southwestward into Virginia.

The major folds are long, linear folds which trend N. 30°-45° E. in the northeastern half of the area; southwestward, the trend of the folds curves broadly to a more northerly direction. In the western part of the upland the fold axes plunge more-or-less steeply and the beds have a curving strike. The plunge of the axes is south or southwest in these folds, and at the sharp curves in strike it is as much as 70°.

The Piedmont upland is bounded on the northwest side by a thrust or thrust zone described as the Martic overthrust (Stose and Stose, 1946, p. 126-128, fig. 30). This fault or zone dips fairly steeply southeastward beneath the upland. The metamorphic rocks of the upland, according to the Stose's interpretation have been thrust northwestward onto the little-metamorphosed rocks of the Frederick Valley.

METAMORPHISM

All of the rocks of the Piedmont upland have been metamorphosed and intensely deformed during Paleozoic orogeny. Metamorphism was contemporaneous with folding and outlasted it in the southeastern part of the upland. Retrogressive changes took place in the schistose Peters Creek Formation and probably in other units in the central part. Grade of metamorphism and grain size decrease from southeast to northwest across the upland.

The Setters Formation and the oligoclase-mica schist of the eastern belt of the Wissahickon Formation, in the southeastern part of the upland, are completely recrystallized granoblastic rocks that belong to the amphibolite facies of metamorphism (Stose and Stose, 1946, p. 78). The minerals in the oligoclase-mica schist are biotite, oligoclase, quartz, some garnet, and, in places, staurolite and kyanite. They show little change in metamorphic conditions throughout their crystallization. Strain shadows in quartz and fragmented garnets cemented by secondary quartz indicate that the schist was subjected to pressure after metamorphism; the metamorphism, however, outlasted deformation.

The schist that makes up most of the Peters Creek Formation, northwest of the oligoclase-mica schist, is a granoblastic mixture of biotite, quartz sericite, and oligoclase. It is finer grained that the oligoclase-mica schist. During post-crystalline movement, the mica was badly crumpled and altered to chlorite. Garnet also was changed to chlorite. These alterations record a change in metamorphic intensity before movement in the area ceased (Stose and Stose, 1946, p. 78-79).

The albite-chlorite schist in the western belt of the Wissahickon Formation, northwest of the schistose Peters Creek quartzite, is composed primarily of chlorite, muscovite, and quartz with albite metacrysts. It belongs to the greenschist facies of metamorphism. Crystallization accompanied folding. "The albites contain a streamline of inclusions that is a residual structure of a former stage of crystallization. The included minerals, biotite and garnet, are of a higher metamorphic rank than the other constituent of the schist" (Stose and Stose, 1946, p. 79).

The Wakefield Marble in the northwestern part of the upland in Carroll and Frederick Counties is much finer grained than the Cockeysville Marble in the southeastern part, and the Silver Run Limestone is the limestone equivalent of the Wakefield Marble. The fine-grained crystalline schists and phyllites of the volcanic series belong to the greenschist facies and are therefore of low metamorphic rank. In places, the phyllites grade into even less metamorphosed slates. Stose and Stose (1946, p. 80) discuss possible evidence of retrogressive changes in the minerals of the volcanic series; however, it cannot be established that the low-rank metamorphism in the western part of the upland is a product of retrogression; in fact, the locally interbanded limestones, slates, and still recognizable tuffs and volcanic flow rocks firmly establish the very low rank of the volcanic series as progressive.

The three copper distics (fig. 1) are in parts of the Piedmont upland that show three different degrees of metamorphism. The Linganore district is in the northwestern zone of low-grade metamorphic rocks; the Sykesville district is in the central zone of fairly low to nearly medium grade metamorphic rocks; and the Bare Hills district is in the southeastern zone of higher grade metamorphic rocks.

TYPES OF MINERAL DEPOSITS

The main primary minerals in the ore deposits of each of the three copper districts are:

Linganore district

ore minerals	*gangue minerals*
bornite (abundant)	manganiferous calcite
chalcocite	quartz
chalcopyrite	chlorite
sphalerite (gray)	pyrite (fairly common)
galena (argentiferous)	hematite (fine-grained)
tetrahedrite (argentiferous)	

Sykesville district

chalcopyrite	gahnite
bornite (fairly common)	actinolite
sphalerite (marmatite)	hornblende
linnaeite	zoisite
carrollite	epidote
siegenite	garnet
magnetite (fine-grained)	chlorite
hematite (coarse-grained)	quartz
	plagioclase feldspar
	talc
	pyrite (little)
	calcite (uncommon)

Bare Hills district

chalcopyrite	anthophyllite
bornite (uncommon)	hornblende
magnetite (coarse-grained)	tremolite
	cummingtonite
	sericite
	pyrite (rare)
	soda plagioclase

In the Linganore district, the copper minerals are coarse-grained in places, but all the other minerals (except quartz and calcite) are fine-grained. In the Sykesville district most of the ore minerals, except magnetite) and some of the gangue minerals (hornblende, garnet, epidote, chlorite, and quartz) are coarse-grained. In the Bare Hills district all of the ore and gangue minerals are coarse to very coarse grained (up to 10 centimeters in length).

Ore deposition was probably partly contemporaneous with the later stages of metamorphism and deformation. In the Linganore district it took place during periods of late brecciation and faulting in the already folded marbles. The ores themselves were shattered during the period of ore deposition.

The mineral deposits apparently increase in temperature of formation and grain size from northwest to southeast. The Linganore deposits are fairly low temperature fine-grained types; those in the Sykesville district are intermediate types; and the Bare Hills deposit is a fairly high temperature, coarse-grained one. This suggests a direct relationship between the type of copper deposit and the grade of metamorphism, the details of which need further study.

Geology

The low-grade metamorphic rocks in the Linganore district are dolomitic and calcareous marble interbedded with quartzite, schist, tuff, slate, and phyllite (fig. 2). Some limestone and dolomite remain locally in the district. The tuffs, slates, and phyllites are of sedimentary origin. Commonly speckled and soft, they are dark gray, greenish gray, and purple in color, sandy, micaceous or granular in texture.

The schists are metamorphosed felsic and mafic lavas, commonly still showing some amygdaloidal structures. Mafic rocks, altered to greenstone, seem to be more common in the southern part of the district. They are predominantly massive to schistose metabasalts composed mostly of epidote, hornblende, chlorite, quartz, and remnants of feldspar and magnetite. The metabasalts are commonly spotted with light-colored flattened elliptical masses of quartz, calcite, and epidote, interpreted by Stose and Stose (1946, p. 64) as distorted amygdules. Light-gray, pink, purple, or gray-blue metarhyolites and meta-andesites are interbedded with the other rocks. They contain similar elliptical masses of calcite rimmed by chlorite in a groundmass consisting largely of hematite, sericite, calcite, and quartz; some laths of feldspar remain.

Quartzites are interbedded with all the other rocks but commonly are not in contact with the marbles. Most of the quartzites, according to Stose and Stose (1946, p. 67), are derived from clastic argillaceous sandstones, but some may be derived from coarse-grained silicified tuffs. Some conglomerate layers contain pebbles of slate, rhyolite and jasper. The quartzites are ridge-makers and form the highest hills in the area.

Fine-grained white marble occurs in closely folded, narrow, discontinuous curving bands and lenses (fig. 2). In the northeastern part of the area the marble grades into grayish-blue limestone with slaty partings. According to Stose and Stose (1946, p. 58-59):

> "The repetition of curving bands appears to be stratigraphic and the marble and metabasalt seem to be interbedded. However, the marble apparently does not merge into the metabasalt or interfinger with it. The repetition of curving bands may be the result of folding of previously formed isoclinal anticlines exposing narrow bands of underlying Wakefield Marble."

Where mineralized, the marble is mottled pink owing to the irregular introduction of manganese into the carbonates and has been called the "variegated" or "calico limestone," or "copper marble" (Mathews and Grasty, 1909, p. 353). This distinctive rock is common near most of the mineral deposits, especially along the contacts with the adjacent phyllites and metavolcanics. Much of the variegated marble is dolomitic and is a healed angular crackle-breccia cemented by clear or milky quartz or manganocalcite veinlets. Some lenses are entirely of variegated marble, such as those at the Liberty mine and the prospects north of it, the Unionville zinc mine, and the Mountain View mine. The variegated marble weathers to black or chololate brown manganiferous soil containing phyllite fragments. Such soil is distinctive and where exposed provides an easy clue to mineralized areas. Lenses of both white and variegated marbles are commonly interbedded with thin layers of slate and metavolcanic rocks.

STRUCTURE

The low-grade metamorphic rocks in the Linganore district dip steeply and are closely folded. The beds in the folds have a curving strike; the fold axes plunge eastward. The marble, quartzites, phyllites, and volcanic rocks are all bent into long curves, and the sequence is repeated six times across the strike. The thinner marble and quartzite layers have tended to flow and break into lentils and boudins during folding.

The largest folds, which trend nearly north in the northern part of the district and northeastward in the southern part (fig. 2), are interpreted by Stose and Stose (1946, p. 124-125) as anticlines that plunge steeply southward. The axes of these folds extend (1) from Johnsville through Libertytown, (2) from one mile east of Union Bridge through Unionville to about a mile northeast of New Market, and (3) southward from New Windsor. Two east-trending cross folds of considerable size are located between New London and New Market, and smaller east-trending cross folds occur west of Unionville and north of the Liberty mine. The Stoses think that the present "steep-axis structure was superimposed during the Appalachian revolution on an already folded anticlinal structure and that the marble and volcanic rocks are in anticlinal uplifts with curving strike."

Faults of pre-Triassic age are common in the district, as is shown by discontinuities and complexities of the quartzite layers and by faults, shear zones, and breccia zones of several directions exposed in the mines.

Few faults are shown on figure 2 because of the sparsity of outcrops in the area and because the interpretation is that of Jonas and Stose (1938). Tensional block faults of Triassic age are mapped in the northern part of the district near Union Bridge (fig. 2) and north and west of the area shown on figure 2.

Many of the ore deposits are in shear and shatter breccia zones or small faults, commonly in areas of structural complexity such as the cross-folded areas, the axes of folds, and small lentils or boudins of marble. These shear and shatter breccia zones are commonly in marble along its contacts with the less competent slates and schistose rocks. Differential bedding-plane movement between the two rocks shattered the marble late in the second period of deformation after the marbles ceased to flow plastically.

The vein in the New London mine is in a westward-trending cross-fault or shear zone. Shearing was renewed along the vein walls after ore emplacement, and the vein was later offset northward by small faults of northward trend that strike nearly parallel to the bedding and schistosity (Butler and McCaskey, 1915).

MINERAL DEPOSITS

Copper deposits and, less commonly, lead-silver-zinc-copper, zinc-copper, and barite deposits have been mined or prospected in the Linganore district (fig. 2). Some silver was recovered from the copper ores and gold was a very minor byproduct. The mineral deposits are mainly confined to the marble, which in most of the deposits is interbedded with metavolcanic rocks and slates. At the Liberty, Mountain View, and Repp mines, lenses of marble are brecciated and almost completely mineralized, but elsewhere the copper is localized in thin contact zones between marble and phyllite or schist, as at the Hines and Hammond prospects, or in small stringers and bunches in the marble near the contacts, as at the Roop and Cox mines. At the New London mine (fig. 2) much of the ore is in a crosscutting fissure vein.

Locally marble is replaced by fine-grained dolomite, manganiferous calcite, quartz, and barite. Other gangue minerals are hematite, chlorite, sericite, and muscovite. Microscopic grains of brown tourmaline, sphene and a little orthoclase have been reported at the New London mine (Butler and McCaskey, 1915, p. 289).

The hypogene copper minerals, in general order of abundance, are bornite, chalcocite, chalcopyrite, and tetrahedrite. Bornite and chalcocite are the main ore minerals in many of the mines and prospected areas in the western part of the district, including the New London and Liberty mines, but chalcopyrite is locally abundant. Farther east, bornite and chalcopyrite are the main ore minerals and primary chalcocite is uncommon. Tetrahedrite was noted as minute grains in the ores from the Dolly Hyde mine, and it is reported from the Liberty mine (Ostrander and Price, 1940, p. 48). It may be the source of some of the silver in the ores.

Lead and zinc minerals are associated with copper minerals in the eastern and central parts of the district. Galena and sphalerite are the hypogene minerals, and some of the galena is argentiferous. Both galena and sphalerite are common at the Cox, Mountain View, and Dolly Hyde mines, but at the Unionville and Roop mines only the zinc and copper minerals are abundant and galena is rare. Much of the sphalerite is fine grained and bluish gray; a little is nearly black. The mineral resembles the blue-gray sphalerite of the Friedensville, Pa. deposits (Miller, 1941) and that of the Howell prospect in easternmost West Virginia near Charlestown (Ludlum, 1955).

Pyrite is an uncommon accessory sulfide. Locally, barite is the principal vein mineral, but elsewhere it is a minor gangue mineral.

In some of the ore deposits, primary minerals are unaltered at shallow depths, but in others supergene copper, lead, and zinc minerals were mined to a depth of 50 feet. The main secondary copper minerals are malachite, chalcocite, tenorite, cuprite, azurite, covellite, and chrysocolla. In the vicinity of Libertytown, secondary copper minerals recovered from manganiferous soils at one time supported a small copper sulfate industry. The only supergene lead minerals known to occur in the district are cerussite and anglesite. Masses, boxworks, and crusts of dirty brown smithsonite intermixed with hemimorphite crystals, flaky tufts of aurichalcite, and white chalky coatings of hydrozincite were mined at the Unionville zinc mine.

Paragenesis.—Some chalcocite was deposited first in coarse grains, and some is intergrown with bornite and transected by bornite veinlets. Contradictorily, much of the chalcocite encloses bornite and is peripheral to it; veinlets of chalcocite cut chalcopyrite and bornite, and some bornite rims chalcopyrite. The deposition of clear quartz persisted through this main sulfide period and may have continued afterwards.

Fine-grained sphalerite and agentiferous galena, where present, were commonly deposited after the main copper sulfides in veinlets, stringers, and replacement grains and masses. Galena preceded sphalerite in deposition. At the Dolly Hyde mine the early sphalerite is brown and the late sphalerite colorless.

The time of deposition of the reported tetrahedrite is not fully known. At the Dolly Hyde mine tetrahedrite is a very late mineral which follows the lead and zinc sulfides.

Origin.—Butler and McCaskey (1915, p. 291) suggest a deep-seated source for the mineralization in the Linganore district, and Overbeck (1916, p. 175-178) concludes that the ores were deposited by hot ascending solutions after metamorphism and plastic deformation were completed. The writers suggest that the deposits were formed at intermediate depths under fairly low temperature mesothermal conditions. The district is in an area of relatively low-grade metamorphism. Sphalerite in the deposits is low in iron, indicating a fairly low-temperature origin. The little iron sulfide that is present is in pyrite rather than pyrrhotite, and iron oxide is in the form of hematite rather than magnetite. The ores are fairly rich in silver, which also suggests a mesothermal origin.

LIBERTY DEPOSIT

The largest ore deposit in the district is that of the Liberty mine (fig. 3). It is in a large crackle breccia zone in manganiferous variegated marble. The Wakefield Marble lens trends northward and is nearly elliptical. It flowed and was contorted during deformation and was later fractured in several directions. The resulting intricate network of intersecting fractures and breccia zones forms a mineralized stockwork of considerable size. The material on dumps of the widespread workings suggests that nearly the entire lens, almost half a mile long and 700 feet wide, is mineralized to some extent with manganese, quartz, and copper.

The richest ore-shoots are in gently northward-dipping tabular bodies that lie somewhat echelon to one another. The marble within the shoots has been shattered to a crackle breccia and partly replaced by dolomite and manganiferous calcite. These in turn have been partly replaced by quartz, chlorite, sericite, and, according to Overbeck (1916, p. 171), barite. The copper-bearing solutions permeated this breccia, selecting the least healed fractures for deposition and the manganiferous marble of the fracture walls for replacement by veinlets and disseminated bunches of coarse and fine-grained chalcocite and bornite, locally intergrown with chalcopyrite.

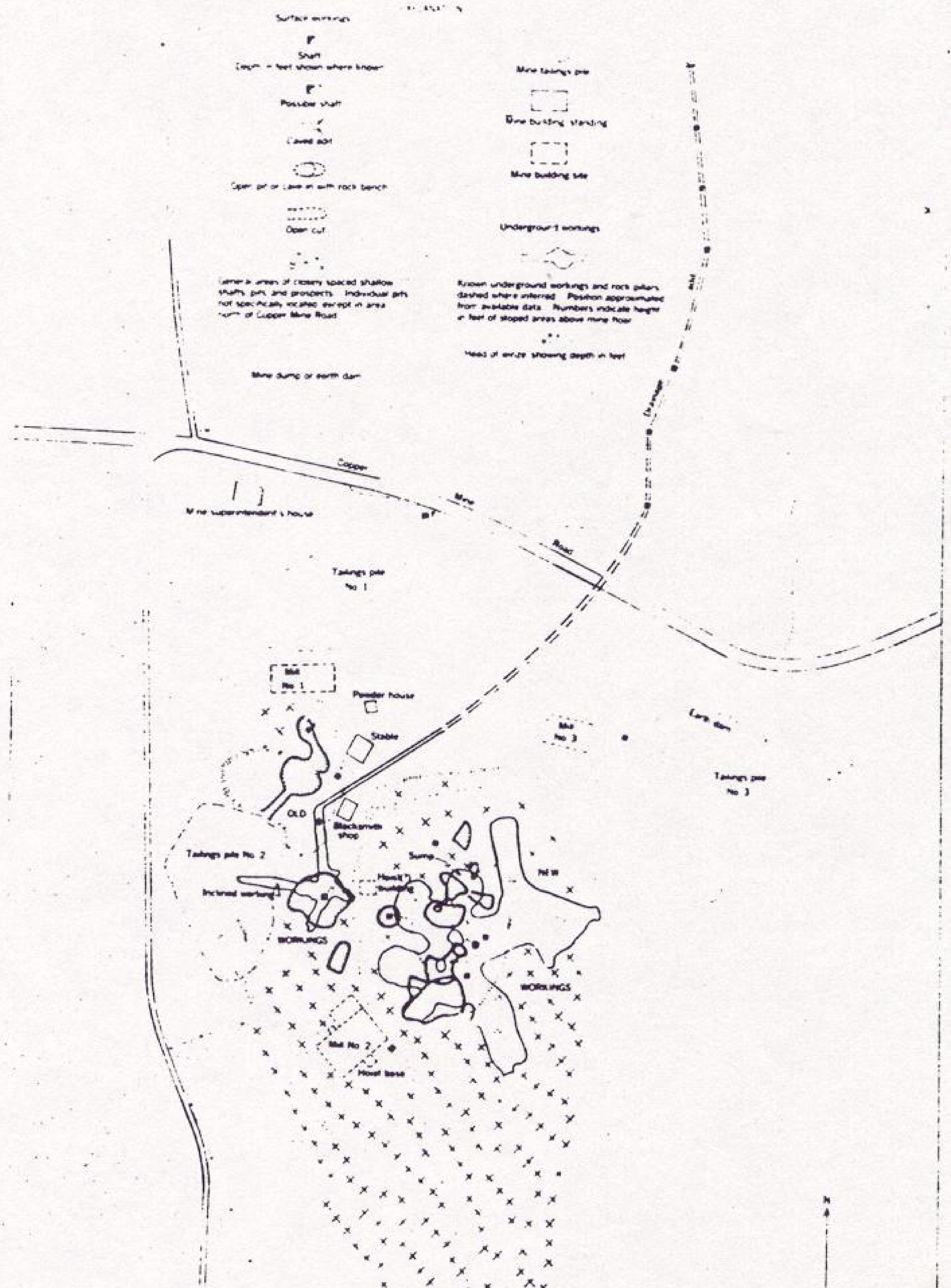


Figure 3 Map of the main workings of the Liberty mine, Frederick County, Maryland

The marble wall rock of the ore shoots is mainly a healed crackle breccia containing manganocalcite and quartz; and copper minerals in widely scattered veinlets, bunches, and disseminations show nearly everywhere. The authors estimate that the visible wall rocks contain between 0.1 and 0.5 percent copper; some local areas contain as much as 3 percent copper and others are nearly barren.

The richest ore shoots were in crackle breccia zones that plunged gently northward where mined by the Old and New Workings. This ore averaged more than 2 percent copper and 4.5 ounces of silver per ton (Stevens, 1906, p. 1035). Local bunches within the ore shoots were much richer, as is indicated by the following analysis of a grab sample from a pile of hand-sorted ore at the Old Workings and from mineralized rock in the pits:*

silver	2.0	ounces
copper	21.24	percent
nickel	.0014	percent
cobalt	.0009	percent

The soil over the entire mineralized marble lens is black or dark brown and contains fragments of wad, limonite, malachite, sooty chalcocite, azurite, and reportedly silver. Copper was recovered from this soil during the early periods of mining.

DOLLY HYDE DEPOSIT

The Dolly Hyde deposit (fig. 4) is in a lens of slightly brecciated marble that is 300 or 400 feet long. According to Jackson (1853a), the lens is about 100 feet wide, strikes N. 75° E., and dips 45° SE.; a northwestward-trending branch of the main lens forms a "Y" that opens westward. Present exposures also suggest a width of 100 feet in the valley flat at the junction of the three arms. However, the marble probably narrows towards the east and northwest and certainly is less than a hundred feet wide in the northwest arm near the shallow shafts. Outcrops and the available history of the mine suggest that the marble is almost eroded away and bottoms at very shallow depths; drilling in 1956 also showed that the lens is shallow.

The marble is surrounded by and in part interbedded with purple and gray metarhyolite and greenish-gray metabasalt and tuffs, which

*Sample no. 153181, U. S. Geological Survey, 1958; analyst Harry Bastron.

make up much of the dump material at the mine. Outcrops indicate that the metavolcanic wall rocks strike and dip generally parallel to the marble lens.

The marble is white where mined but gray at the single exposure southeast of the mine. Originally the marble was probably fine grained and saccharoidal in texture; but locally it has been replaced by dolomite in coarser grains and in rhombohedral crystals and by manganiferous calcite, possibly in the early stages of mineralization.

The known mineralized rock from which ore was mined is confined to the full width of the northwest arm (about 70 to 100 feet) of the lens and to the junction area of the three arms. The ore appears to form a crescent-shaped body within 120 feet of the northerly edge of the marble lens and following it. Northwest of the engine shaft, lines of old pits suggest that the mineralized zones strike north, are from 30 to 100 feet long, and extend en echelon across the marble lens at intervals of 20 to 30 feet apart. According to available descriptions, the mineralized zones near the east shaft strike eastward and dip southward near the contact between the marble and metavolcanics. Jackson (1853a) reports that mineralization was richest at the Y-split of the marble lens in the western part of the mine. At this point copper ore was sufficiently abundant to be worked for a width of 3 feet and could be regarded as good ore for 2 feet.

The Dolly Hyde ores are very fine grained and occur in the brecciated marble as small, very irregular replacement veinlets; clusters of minute replacement crystals; and thin, hairlike veinlets filling fractures and cementing breccia fragments. Most of the fracturing is pre-ore, but in one specimen post-ore fracturing was noted.

Although described and mined as a copper deposit, the Dolly Hyde is more strictly a silver-bearing copper-lead-zinc deposit. The ore minerals are bornite, chalcopyrite, and, locally, argentiferous galena and sphalerite. Argentiferous galena was abundant at the eastern end of the mine workings. The sphalerite is very difficult to identify because nearly all of it is very fine grained and colorless.

Bornite is the most common of the sulfide minerals. Pyrite in coarse crystals occurs with the bornite as an early mineral and is mostly replaced by it. Chalcopyrite and galena are abundant and are somewhat intermingled with bornite, although for the most part the three minerals tend to occur in separate veinlets. The galena is accompanied by abundant colorless sphalerite and rare marmatitic sphalerite. Discrete grains and clusters of colorless sphalerite are also found near the galena in the white marble, from which they are scarcely distinguishable. Sphalerite is rare or absent in the bornite- and chalcopyrite-rich areas.

Whitney (1854, p. 318) reports that the argentiferous galena contained 45 to 50 ounces of silver per ton. One small cluster of a shiny metallic mineral with marked conchoidal fracture and high luster is probably tetrahedrite or tennantite and may indicate a source for some of the reported silver values. It appears to be a fairly late mineral and extends out as a veinlet from the main copper minerals.

A little sooty chalcocite coats and replaces partly oxidized ores. Malachite, smithsonite, and limonite were also noted. Dark manganiferous soil is abundant, containing fragments of chalcocite and malachite. This "black dirt" accounted for much of the reported copper production. When washed it yielded a concentrate that contained about 60 percent recoverable copper ore.

Only a little vein quartz was noted in the area of the deposit, mostly in veinlets in the metavolcanics accompanied by chlorite and dark-red massive hematite. The marble contains a little white flake sericite.

COX GROUP OF DEPOSITS

The deposits at the Cox mines and the Cox (Mountain View) mine (fig. 2) are both in small brecciated lenses of manganiferous marble trending northward. The marble lenses are enclosed by purple to green soft fissile shales in which are lenticular quartz veins. Two very small lenses are exposed at the Mountain View mine, and the Cox mines to the north probably are in one larger lens. The marble is cut by a few small curved mineralized shear planes, with which are associated healed breccias of manganiferous marble. In the Mountain View mine, at least, the mineralized areas apparently are more abundant near the shale contacts, although they are not restricted to them.

The sulfides at the Mountain View mine are sparse and consist of dark-gray and green transparent sphalerite, some galena, a little chalcopyrite, bornite, and pyrite. Pink manganocalcite, specular hematite, green fluorite, barite, chlorite, and a little vein quartz are associated with the ore. Four samples of "supposedly run-of-mine ore" collected in the 1940's showed the following range of content (Singewald, 1946, p. 161-162):*

*Analyst not known.

gold	0.20-0.10 ounces per ton
silver	tr -1.16 ounces per ton
copper	0.95-1.20 percent
lead	1.60-4.75 percent
zinc	1.42-6.30 percent

At least one sample of copper minerals selected from the dump was rich in silver, assaying 33.14 ounces per ton.

Most of the zinc-lead-copper minerals are in fine-grained replacement stringers half an inch to 2 inches wide in and along the curved shear fractures; the rest cement and replace the healed breccias and the coarser marble near the fractures. Coarse grains of milky quartz and deep pink calcite up to 1 cm across replace the marble adjacent to the sulfides; the quartz and calcite are in turn veined and replaced by the sulfides.

Partial oxidation of the sulfides at the Mountain View mine is restricted to less than 10 feet beneath the surface. Smithsonite, cerussite, anglesite, earthy manganese oxide, and malachite stains are the main supergene minerals noted. Sulfur and chalcanthite are reported (Ostrander and Price, 1940, p. 48-49), but may actually be from the Cox mines to the north.

No sulfides were seen in place at the Cox mines north of the Mountain View, but an old pile of hand-sorted copper-lead ore is near an old shaft. It contains nearly pure masses up to 3 or 4 inches in diameter consisting of chalcopyrite, bornite, galena, and coarse blue chalcocite as major primary minerals and black to dark-gray sphalerite, quartz, pyrite, barite (?), and calcite as minor minerals. The wall rock is partly dolomitized marble. The secondary minerals noted are gray earthy anglesite, cerussite, tenorite, limonite, malachite, azurite, chrysocolla, sooty chalcocite, aurichalcite in pale-blue pearly flakes, and chalky white hydrozincite (?). A partial analysis of a grab sample of coarse lump ore from this pile follows:*

gold	none
silver	12.8 ounces per ton
lead	35.86 percent
copper	20.95 percent
zinc	3.02 percent
cobalt	0.012 percent
nickel	0.022 percent

*Sample no. 153179, U. S. Geological Survey laboratory; analyst Harry Bastron, 1957.

The Unionville zinc deposit is probably a northward-trending pod of mineralized breccia in a band or lens of marble dipping eastward fairly steeply. The marble near the mine as shown by drill hole cores is light gray to pink and fine-grained; much of it is dolomitic and manganiferous. Locally it is shattered and brecciated and the fractures are healed with quartz and calcite. Interbanded with the marble are gray, purple, gray-green, and pink metarhyolite, meta-andesite, amygdaloidal flows, tuffs, and agglomerate. In places, varicolored phyllites and slates are also interbanded. Other mineralized marble bands are exposed south of the mine.

The primary ore minerals in the Unionville deposit are gray to black sphalerite, chalcopyrite, bornite, and pyrite. Some late fractures in thin zones are unhealed and locally contain copper and zinc minerals, but the sphalerite is more commonly as fine-grained replacement crystals in favored marble bands. Galena is reported by the owner in outcrops in the vicinity, but the writers saw none. The gangue consists of manganocalcite, coarse white dolomite, and clear quartz as disseminated replacement masses in marble and as thin veinlets cementing marble crackle breccia.

Most of the primary minerals have been oxidized to supergene minerals. Smithsonite, which occurs as dirty brown and white spongy masses, is the main secondary zinc mineral. Associated with it are soft flaky white hydrozincite, colorless small crystals of hemimorphite, and pearly blue flakes of aurichalcite. Other secondary minerals include malachite, tenorite, sooty chalcocite, limonite, and earthy manganese oxides. The oxidized zinc and copper minerals were probably the principal ores to the depth mined.

Black or chocolate-brown manganiferous soil containing fragments of white vein quartz overlies the ore deposit and forms a wide dark band that extends at least half a mile along the hill southeast of the mine.

ROOP DEPOSITS

The very small scattered Roop deposits south of New Windsor (fig. 2) consist of copper, zinc, and lead minerals in blue-gray limestone, which is partly altered to white marble close to its contact with chloritic metabasalt. Banding in the marble is parallel to the metabasalt contact. The minerals occur as scattered lean replacements and veinlets in brecciated marble. Some of the small deposits are in breccia pipes or pods up to 15 feet in diameter lying along marble-metabasalt contacts and elongated down the dip of the contacts; others are small irregular replacement veins in the marble near metabasalt contacts. The observed ore veins strike and dip parallel to the contacts.

The primary copper minerals are fine- to coarse-grained chalcopyrite, bornite, and chalcocite. Some of the ore bodies contain only copper minerals, in a gangue of manganocalcite, quartz, and a little radiating specular hematite. Others are mostly colorless to dark-gray sphalerite, accompanied by a little galena, chalcocite, bornite, and chalcopyrite. Weathering products are manganiferous soil, malachite, azurite, covellite, tenorite, smithsonite, hydrozincite, and limonite, but oxidation extends only a few inches or feet into bedrock.

NEW LONDON DEPOSIT

The New London copper deposit (fig. 2) is unique in the district because much of the ore consists of primary sulfides in a crosscutting fissure vein that probably is a fault. The vein strikes N. 69° W. and dips southward at 70° (Overbeck, 1916, p. 175). It cuts across the phyllite, marble, schist, and quartzite units, which in the vicinity of the mine strike N. 20°-45° E. and are vertical or dip eastward at 80° (Haeusser, Paynter, and Genth, 1864, p. 10).

Near the main ("new") shaft the fissure crosses an impure lens of marble about 60 or 70 feet thick that is interbanded with soft gray phyllite. West of the main shaft the steeply dipping marble overlies soft crumpled black phyllite. East of the shaft the marble is overlain by a fairly thin unit of epidote schist, then quartzite, and then about 200 feet east of the shaft another unit of soft black phyllite (Butler and McCaskey, 1915, p. 285).

The ore body along the fissure ends on the 200-foot level against a fault about 280 feet east of the main shaft. The attitude of this cross fault is not specified, but probably it is one of several northward-trending cross faults that offset the vein (Overbeck, 1916, p. 172). Overbeck also mentions a well-marked fault exposed "a short distance north of the mine."

The fissure vein contains more or less copper throughout its length (Haeusser, Paynter, and Genth, 1864, p. 19), but the commercial ore is largely restricted to the part about 300 feet long between the two black phyllite units which nearly seal off the vein toward the east and west. The richest ore is in a shoot that is about 60 feet wide along the fissure and is confined to the impure marble and gray phyllite lens. The shoot rakes about 45° towards the southeast down the plane of the fissure. It is 2 to 6 feet wide. On the 200-foot level ore extends from 20 feet west of the shaft to 280 feet east of it, the greatest length recorded along the vein. In the upper levels the ore shoot is much shorter; between 60 and 70 feet are recorded (Haeusser, Paynter, and Genth, 1864, p. 11; Ducatel, 1840, p. 22). Apparently it is much more discontinuous and spotty below the 200-foot level, perhaps in part because of offsets by cross faults. In this lower part of the mine nearly all the ore was found east of the main shaft (Charles Cashour, oral communication, 1958).

The ore in the main shoot is of two general types: (1) massive coarse-grained vein ore, and (2) fine-grained schistose ore. Massive ore consists of masses of primary chalcocite cut by bornite veinlets. The sulfides are associated with much pink and white coarsely crystalline calcite, quartz, and a little barite (Butler and McCaskey, 1915, p. 286; Overbeck, 1916, p. 173). Schistose ore consists of phyllite and marble banded parallel to the fissure; some of the marble bands are replaced by fine-grained calcite, quartz, chalcocite, and bornite, and a little pyrite. The calcite, quartz, and sulfide of this type of ore have been crushed and recrystallized; possibly the result of late dynamic metamorphism (Butler and McCaskey, 1915, p. 290).

The massive ore occurs in the wider parts of the vein where the marble is relatively pure. The banded or schistose ore occupies the margins of the vein where it is wide and all of the vein in narrower parts. Where the two ore types come together, there is commonly a transition zone from one type to the other.

Near the walls of the vein, and in places at some distance from them, chlorite, specular hematite, and muscovite are abundant. Micrograins of tourmaline and titanite are locally abundant, and orthoclase and actinolite are present in small quantities.

The ore body was largely oxidized from the surface to a depth of 80 feet into a mixture of malachite, cuprite, probably sooty chalcocite, manganese, and iron oxides. Below this depth, it was only very locally coated with a little malachite.

The ore is reported to have contained enough silver and free gold to help pay for mining costs (Charles Tregoning, oral communication, 1959).

Sphalerite, galena and chalcopyrite and their oxidation products occur in some abundance in the Farmers Cooperative Limestone quarry about 1 mile east of New London in an eastward-trending nearly vertical band of Wakefield marble. The sulfides occur as replacements of the marble at the contact of the adjacent Ijamsville Phyllite, and in thin replacement veins, bunches and stringers within the marble band. The veins are similar to those in the New London mine.

Liberty mine

Oldest of the Linganore district copper mines is the Liberty mine, 2 miles north of Libertytown and three-fourths of a mile west of State highway 75, on the south side of Coppermine Road (fig. 2). Along with the Mineral Hill mine in eastern Carroll County, it was possibly started by a group of English miners about 1750. The ore was smelted at a furnace in Carroll County. In 1765 Dr. John Stevenson of Baltimore formed a partnership with Stephen Richards to work the mine for copper, under the management of James Smith. The work was not at first successful, but in 1767 some ore was shipped to London, and just before outbreak of the Revolutionary War "much ore" was shipped (Robinson, 1939, p. 24). In 1780 the property was advertised for sale but not sold, and the following year Stevenson erected a furnace, refinery, and rolling mill at Deer Park in Carroll County, to which he sent "many wagonloads" of ore from the Liberty mine. During the closing years of the war the mine was reportedly the largest single producer of copper in North America (Robinson, 1939, p. 24), but it apparently did not continue in operation after the war.

In 1838 Isaac Tyson, Jr., Baltimore mining magnate, acquired from Evan T. Ellicott a half interest in the "land, copper mines and furnaces and mineral rights."* He built a small furnace to smelt the ore along the south fork of Israel Creek, half a mile north of the mine, but it was reportedly abandoned the following year. There is no record of subsequent work until the prospectus of the Liberty Copper Mining Co. appeared in 1864, and the assertion is made therein that Tyson and Ellicott did no further mining.

The new company acquired the property from the executors of Tyson's estate and developed it extensively. Large quantities of copper ore probably were produced between 1864 and 1874. In 1870 alone the product was 153 tons of metallic copper valued at $65,000, and 65 men were employed (U. S. Ninth Census, 1870, p. 762). A gravity concentration mill north of the old workings (fig. 3, no. 1) was probably built during this active period. Available information and the size of the remaining tailings piles indicate that it successfully concentrated a large tonnage of ore.

The property later changed hands several times. It was sold under a mortgage in 1876 or 1878 to the Maryland Copper Mining Co. Inter-

*Manuscript record book of Isaac Tyson, p. 172. In Maryland Historical Society library, Baltimore, Md.

mittent production continued at least until-1885, although no ore was produced in 1880 (Pumpelly, 1886b, p. 977).

In 1899 the mine was sold to the Liberty Copper Mining Co. of New York State (Engineering and Mining Journal, 1899); the shafts were pumped out, and several carloads of ore that had been stockpiled from previous operations were shipped. The company was reorganized in 1901 as the Liberty Copper Mining and Milling Co. and a new concentration mill (fig. 3, no. 2) was built (Engineering and Mining Journal, 1901). The new workings seem to have caved during development work and the company failed. In 1905 and 1907 the Virginia Consolidated Copper Co. reworked part of the dumps and produced a little copper from experimental work. A third gravity concentration mill with jigs was built northeast of the mine by J. Labaw and L. Vogelstein. During 1916 and 1917 they recovered 120 tons of copper from 13,500 tons of old tailings.

The Liberty mine workings now consist of many open cuts, caved shafts, flooded stopes, prospect pits, and dumps in an area that extends southward about 1,400 feet from Coppermine Road and is as wide as 600 feet (fig. 3). An adit more than a quarter of a mile long entered the mine area from the north and provided drainage to a depth of 60 feet (Williams and McKinsey, 1910, p. 276). It is now partly caved and clogged. Half a mile north of Coppermine Road and the mine is the site of an old furnace, where ore was smelted about 1839. The Israel Creek copper prospects (see p. 39) are west and northwest of the furnace site (fig. 2).

The main workings are in two groups, known as the Old and New Workings (fig. 3). The Old Workings, to the west, are said to be 125 feet deep; one shaft, however, is reported to be almost 400 feet deep (Singewald, 1946, p. 157). The New Workings include several open cuts and a series of room and pillar stopes that extend very irregularly underground over an area about 100 feet by 350 feet. The main level of these stopes is less than 100 feet below the surface; access was by an incline at the southwest end (fig. 3). The stopes are partly caved.

New London (Linganore) *mine*

The New London mine is in the narrow wedge of land that forms the southwest corner of the crossroads in the town of New London, Frederick County (fig. 2). The main shaft and mill site are along the south side of the county road about a quarter of a mile west of the crossroads.

Isaac Tyson, Jr., is credited with the discovery of the deposit about 1835, but his lease* with William Hobbs, the property owner, refers to the property as the "tract called Drum mine," suggesting that the deposit was known and possibly prospected prior to Tyson's interest. The New London mine was opened by Tyson in 1837 and was profitably worked until about 1853. Development work at the mine in 1860-1861 was terminated by the Civil War.

In 1864 the New London Copper Mining Co. published its plans to reopen the mine (Haeusser, Paynter, and Genth, 1864); results are not known. In 1884 the mine was reopened by a Mr. Kochendeffer (Frederick Daily News, 1884; Charles Cashour, oral communication, 1958). A new steam pump was installed and some ore was produced, but in 1888 the property became idle again owing to litigation. About 1903 or 1904 E. S. Wertz attempted to reopen the mine.

In 1907 the Linganore Copper Co. began development and production. They built a gravity concentration mill in 1911 and milled a considerable tonnage of ore than contained between 0.54 and 2.2 percent copper. The mill proved inadequate, so that additional equipment had to be installed to treat the mill fines. In 1913 the company merged with the Eagle Metallic Copper Co. of Pennsylvania to form the United Milling and Copper Smelting Co., which produced ore and concentrates in 1914, 1916, and 1917. The mine was operated with moderate success during this period, although an increased flow of water caused some pumping difficulties during the last years. The mine was closed in 1917 or early in 1918 because of poor prices, increased costs, and the death of the mine superintendent (oral communications from Charles Cashour, 1958, and C. F. Tregoning, 1959).

Information is available about the mine at several periods in its history. In 1839 the shaft was 114 feet deep; the ore averaged 13 percent copper, and when sorted yielded 20 percent (Ducatel, 1840, p. 22). In the 1860's the workings consisted of a very irregular shaft 70 feet deep vertically and then inclined steplike down the dip of the vein for 130 feet. An adit extended 350 feet southward from Ben's Branch to drain the shaft at 60 feet below the collar. The first regular level on the vein was at 80 feet; other short levels were at 118, 160, 173, 190, and 200 feet with connecting stopes along the main ore shoot. In 1864 Genth estimated that 500 tons of ore piled at the mine would "average not less than 3 percent" copper (Haeusser, Paynter, and Genth, 1864, p. 21).

By 1909 the old shaft had been made into an incline, and the old stopes above the 173-foot level were pretty well filled with waste (Butler

*Recorded in a manuscript record book of Isaac Tyson, p. 215; in the Maryland Historical Society library, Baltimore, Md.

and McCaskey, 1915, p. 285). Overbeck*, who visited the mine in 1909 and again in 1911, states that practically all ore above the 118-foot level and 120 feet from the shaft was mined out. A new main inclined shaft, probably a short distance east of the old one, was 210 feet deep with a stope in the bottom. This shaft was later deepened to 435 feet (Singewald, 1946, p. 155; Charles H. Tregoning, oral communication, 1942); the 200-foot level was extended 320 feet eastward and at least 75 feet westward from the new shaft; and levels were driven at 220 and 300 feet. During this later period an exploratory drift is reported to have extended 400 to 500 feet towards the southeast; perhaps this was the extended 200-foot level. Some stoping was done in the floor of the 300-foot level; the present owner (1959) and former underground superintendent, Charles Tregoning, states that ore remained in these stopes when the mine was closed in 1917.

The ore shoot on the 200-foot level was reported to be 150 feet long and the ore to average 3.6 percent copper; ore sampled at a depth of 210 feet averaged 4.9 percent copper (Butler and McCaskey, 1915, p. 286). Hand-sorted concentrates produced from this ore contained between 10 to 11 percent copper.

Old reports state that during the nineteenth century surface exposures of the vein were found for several hundred feet northwestward from the mine. The Copper Handbook (Stevens, 1910, p. 1075) states that two fissure veins 4 to 5 feet wide were worked on the property. Several nearly barren prospects lie southeast of the mine (fig. 2). Shallow shafts in copper-bearing marble were sunk southwest of the mine and north of the mine across the valley, and a few outcrops of copper-bearing marble lie northwest and north of New London. Some of these areas were prospected in 1955 by the American Smelting and Refining Co.

Dolly Hyde mine

The old Dolly Hyde copper mine is on both sides of Dollyhyde Creek about three-quarters of a mile east of Libertytown, Frederick County, and about a quarter of a mile south of State highway 26 (fig. 2). The mine was begun in 1839 as shallow diggings in manganiferous malachite- and chalcocite-bearing soil. It was worked for a total of about 10 years and produced approximately 58 short tons of metallic copper.

The deposit was opened in 1839 by Richard C. Coale and Co.** as

*Overbeck, R. M., 1915, The copper ores of Maryland, unpublished Ph.D. dissertation, Johns Hopkins University.

**The articles of agreement on formation of this company are recorded on pages 54-66 of a manuscript record book of Isaac Tyson, Jr., in the Maryland Historical Society library, Baltimore, Md. Other partners in the company were William Coale, Thomas Sappington, and Jacob Fox.

a group of shallow diggings in the dark, copper-bearing soil along Dollyhyde Creek. Washed copper concentrates were produced from this near-surface material for several years, but production ceased about the end of 1842. In 1846 the mine was leased to Isaac Tyson, Jr., who reactivated it and reported production until 1853, when he sold it to the Dolly Hyde Copper Co. Visitors were continually impressed by the ore deposits at the Dolly Hyde mine while it was in operation. Optimistic predictions were made by the State Geologist in 1839 (Ducatel, 1840); C. T. Jackson (1853a) in 1846 and again in 1853; a visiting German geologist about 1850 (Dieffenbach, 1858, p. 67); and the State Chemist later in the 1850's (Philip Tyson, 1860). Despite these predictions, and despite additional development work that in 1854 satisfied "the most sanguine expectation" of the owners, the mine became flooded in 1855, and it failed to respond to subsequent attempts in 1907 by the Linganore Copper Co. to return it to commercial status. The deposit was diamond drilled in 1955-1956 by the Parker Mining and Development Co.

The oldest group of workings at the Dolly Hyde mine is a cluster of shallow shafts and pits in the northwestern part of the area (fig. 4). These are probably the diggings begun in 1839 in the malachite- and chalcocite-bearing soil.

The main workings consist of two shafts into unweathered marble, one just east of the creek in the valley flat and the other, now filled (1958), west of the creek near the northeastern end of the stone ruins of an old pump house. The actual depths of these shafts are not known, but the size of the dumps indicates that neither is more than 100 feet. A prospectus illustration (Jackson, 1853a) shows a 70-foot shaft, from the bottom of which extends a short level. A level from one of the shafts, about 20 feet below the surface, was 55 feet long and 5 feet wide in 1853; plans were being made to drive another level from the western shaft at about 120 feet, and a cornish pump was installed at about this time. The work of deepening the mine was started but not completed (Tyson, 1860).

The mine dumps have been partly removed, probably for fill or road material. The amount of remaining dump material indicates that workings connected with the shaft east of the creek were largest and most extensive. Undoubtedly some stoping was done in the eastern workings. Much of the remaining dump rock is sparsely mineralized, whereas the dumps of the main or pump shaft are composed mostly of barren rock.

Repp mine

The Repp mine is 1 mile southeast of Johnsville and half a mile north of Coppermine Road in Frederick County (fig. 2). According to local tradition, it was worked before the American Revolution, but the main workings appear to be more recent. The Linganore Copper Co. may have done some work at the Repp mine between 1907 and 1913 (Charles Cashour, oral communication, 1958). The mine was partly cleaned and sampled in 1941 by L. A. Baumgardner and E. R. Gill, Jr.

The Repp mine consists of two main groups of workings about 600 feet apart, and a shallow shaft, trench, and several prospect pits between the two. At the southern workings, an adit in an open cut is inclined northward into water-filled stopes which, in turn, are connected to the surface by a shaft. Another shaft is about 100 feet east of the open cut. At the main northern workings a shaft 45 or more feet deep leads into small open stopes to the north and east.

The Repp deposit consists of chalcopyrite, bornite, and chalcocite in dense white dolomitic marble and pink to purple brecciated marble. Manganocalcite is an abundant gangue mineral, and milky vein quartz is more abundant than at most of the other mines. Small, nearly pure masses of the primary copper minerals and fragments of copper carbonates are notably abundant in the older part of the north dump. The eastern part of the dump is very lean in copper and contains mostly purple and gray metavolcanic rocks.

Six samples from the dump and underground workings, assayed in 1941, ranged from 0.12 to 5.79 percent copper, 0.23 to 1.44 ounces of silver, and 0.01-0.06 ounces of gold per ton (Singewald, 1946, p. 1957).

Cox group of mines, including Cox mines and Mountain View lead mine

The Cox group of mines is 1¾ miles northeast of Johnsville, Frederick County (fig. 2). One group of old shafts and open cuts now known as the Cox mines begins 400 feet north of the old stone Dunkard church and extends about 500 feet northward along the side of the hill. Another group of openings about 1,000 feet southeast of the stone church has come to be known as the Mountain View lead mine. Both groups of mines were on the original Cox property.

The Mountain View lead mine, sometimes also called "the Cox mine," consists of an incline 15 feet deep, which opens into a stope 65 feet long, 35 feet wide, and 15 feet high; southwest of the incline is an irregular open cut—probably originally an adit and a second shallow stope, now caved for at least 30 feet of its length (Singewald, 1946, p. 161). According to Singewald, these workings were also known as the Six lead mine and the Shivers mine, and were worked about 1880 for lead. Zinc ore was discarded on the dump. The present Mountain View lead mine was reportedly reopened briefly in 1910 and worked for a year or so (L. A. Baumgardner, oral communication, 1942). The old workings were unwatered and inspected by Gill, Howe, and Baumgardner in 1941 and 1942. A small quantity of lead ore has been produced; no production records are known, but the size of the known stopes indicates a few hundred tons.

The northern workings of the Cox group of mines are more commonly known today as the Cox mines. Their history is not known, but some mining reportedly was done about 1845 or 1850 by slave labor. Copper ore is said to have been produced, but there are no records of production.

The mines consist of a group of northward-trending open cuts in marble, and shafts indicative of fairly extensive past operations. The southernmost cut opens towards the west and has a partly filled incline or tunnel into the east face. The condition of the workings suggests that the mine was last worked in the latter part of the nineteenth century. Farther north are two areas of very old brush-covered cuts and pits that may date from the eighteenth or the early part of the nineteenth century. Northwestward about 50 feet from the the northernmost group of cuts is a shaft of more recent age, possibly contemporaneous with the southern open cut.

A "Mountain View lead mine" which was worked between 1890 and 1893 may have been one of the Cox mines or may have included both localities. An old ore pile of partly oxidized lead-copper ore (see p. 27 for analysis) about 100 feet northwest of the northernmost Cox shaft contains copper-lead-zinc ores that fit the description of the ore Williams (1891) saw at "Mountain View lead mine" much better than the zinc-bearing material remaining on the dump of the mine now known as the Mountain View. Aside from this one ore pile, very little mineralized rock remains in the dumps and workings at the Cox mines.

Unionville zinc mine

The Unionville mine, the only productive zinc mine known in Maryland, is about three-fourths of a mile west-northwest of Unionville, Frederick County (fig. 2). The mine workings lie beneath the fill of Maryland highway 26, but some of the mine dumps remain to the south of the old road on the farm of Mr. Paul E. Young.

The deposit of oxidized zinc and copper ore was apparently discovered in 1879 on what was then the Thomas O. Pearre farm. The mine was opened and operated by William A. Ingham and General William Lilly during 1879 and 1880 but probably was closed shortly afterwards.

In 1880 the mine employed 15 men and produced 672 tons of zinc ore valued at $7,200 and 2 tons of other ore, probably copper (Pumpelly, 1886b, p. 804). Whether additional ore was produced is not known.

Mr. Young, the present owner, reports that before the highway was relocated the mine was a fair-sized open pit resembling a small quarry, the bottom of which was filled with soil. Underground workings probably existed, as the Tenth Census report mentions 10 men and a boy working underground. An area southeast of the mine was prospected by the American Smelting and Refining Co. in 1954 and 1955.

Roop mine

The Roop mine is on the Smeltser farm about 1¾ miles south-southwest of New Windsor, in western Carroll County (fig. 2). Shallow shafts, pits, and trenches are scattered over an area 2,400 feet from north to south and 1,200 feet from east to west. Two deeper shafts known as "Old" and "New No. 1" are in a marble quarry southeast of the farm house and south of the barn. These were 45 to 50 feet deep in 1881; later, one or both may have been deepened to about 60 feet.

Mining began in 1879 after copper and zinc minerals were discovered in small marble quarries on what was then the Roop farm. A small quantity of cobbed copper ore was sent to Pope, Cole and Co. in Baltimore in 1880; a few hundred tons of oxidized zinc ore may have been shipped from this locality in 1879. The mine is enthusiastically described by Frazer (1881); however, the small, scattered deposits failed to meet expectations and work was soon discontinued.

At the south edge of New Windsor, about a mile north of the Roop mine, copper was prospected in a well at a former tollhouse on the Liberty road. A large dark-brown lenticular area of manganiferous soil is exposed in a field about half a mile north of the Roop mine west of a small stream that flows northward to New Windsor.

Eiler prospect

The Eiler prospect is south of the Liberty Turnpike about 1½ miles east-northeast of Johnsville, Frederick County (fig. 2).

It was prospected about 1941 by L. A. Baumgardner and E. R. Gill, Jr., under lease from U. J. Eiler. No ore was shipped, and the shallow pit or shaft is now (1965) completely obliterated.

Galena and sphalerite are deposited in marble; the sparsely mineralized rock is reportedly similar to that at the Mountain View mine. A hand sample reportedly assayed 0.01 ounce Au and 0.12 ounce Ag per ton, 0.46 percent Cu, 10.20 percent Pb, and 0.40 percent Zn (G. H. Espenshade, written communication from L. A. Baumgardner, 1943).

Hammond (Pittinger) prospects

The Hammond (or Pittinger) prospects are about three-fourths of a mile southwest of Libertytown, Frederick County (fig. 2). A group of shallow pits in marble extend northeastward for about 500 feet down a hill near the contact between Wakefield Marble and purple metavolcanic rocks. Dark manganiferous soil similar to that at the Dolly Hyde and Liberty mines is abundant, particularly at the northernmost pits; it may have been dug on the property in the late 1830's or early 1840's for making copper sulfate (Ducatel, 1840, p. 22, 23). The more southerly pits show sparsely mineralized marble, slightly brecciated, either in place or as fragments on the dumps. These pits were probably the work of the Frederick County Copper Mining Co. in 1854 (Williams and McKinsey, 1910, p. 276).

Copper minerals at the Hammond prospects include chalcocite, a little bornite, and secondary malachite and covellite. Small masses of red hematite are also found on the dumps. Gangue minerals are coarse white calcite, brown and pink manganiferous calcite, and clear to milky quartz. Traces of barite and chalcocite were noted in a marble outcrop about 500 feet south of the southernmost pit.

Four samples of ore from the Hammond prospects, assayed in 1941, averaged 1.12 percent copper and 0.12 ounce of silver per ton (unpublished data, G. H. Espenshade).

Hines prospects

The Hines prospects are two similar groups of shallow pits about 2,000 feet north of the Hammond prospects (fig. 2). The two groups are about 200 feet apart in a north-south direction. Dark manganiferous soil is abundant. Sparse stringers of chalcocite and veinlets of quartz and calcite occur in the marble. The property was prospected in 1854, possibly by the Frederick County Copper Mining Co.

Israel Creek prospects

Two clusters of prospects occur along the southwest side of the south branch of Israel Creek, west of the copper furnace site and between a half and three-fourths of a mile north of the Liberty mine (fig. 2). A large lens of brecciated marble is partly replaced by manganocalcite and quartz. Sparse fine-grained replacements and veinlets of chalcocite and bornite were prospected.

P. G. Sauble barite prospects

The Sauble barite prospects are in Wakefield Marble on two adjacent hills on the east side of Beaverdam Creek about 1½ miles southeast of Johnsville (fig. 2). The southern prospect was formerly a marble quarry operated for local use. The barite was sorted and thrown aside; as far as is known, none was shipped (Watson and Grasty, 1916, p. 531).

The barite occurs in lumps, small bands, and stringers in brecciated and crushed marble. Much of it is in large white masses with cleavage faces, but small groups of tabular crystals are present (Ostrander and Price, 1940, p. 48). It is similar to barite found as a gangue mineral in the copper deposits and undoubtedly was deposited from the same ore-bearing solutions.

Other barite prospects are reported west of New London (fig. 2) and on the northwestern slope of Sugar Loaf Mountain near Lily Pons about 17 miles southwest of Libertytown.

Geology

The Sykesville district is in the central part of the crystalline rocks of the Piedmont upland (fig. 1). The copper-iron mines and prospects are in narrow belts consisting mainly of chlorite-amphibole schist and gneiss and talc schist. They extend from the northern part of western Howard County, northeastward across eastern Carroll County into western Baltimore County northeast of Finksburg. Minor copper occurrences that are reported (Tyson, 1860, app. p. 15) along a northeast-trending line of serpentine bodies and a fault may mark an extension of this belt across Baltimore County into Harford County. Some unsuccessful prospecting was done on small deposits of magnetite and copper minerals on this line near Bluemount, south of Whitehall near the forks of the Gunpowder River about 22 miles north of Baltimore, and also near Cooptown, Harford County (Tyson, 1862, p. 65-66).

The principal country rocks in the district and adjacent parts of Howard, Carroll, and Baltimore Counties are schists and gneisses of uncertain age (late Precambrian (?) or Paleozoic?), the foliation of which strikes generally northeastward (fig. 5). Included are: (1) an extensive area of quartz-mica paraschists described by Hobson (1964, p. 117) as metagraywacke belonging to the Peters Creek Formation; (2) several irregular belts of chlorite-amphibole schist and gneiss; (3) lenses of talc schist and peridotite; and (4) a large, irregular mass of Sykesville Formation, a rock described by Hobson (1964, p. 103) as "pebble and boulder bearing arenaceous to pelitic metamorphic rocks" (but in this local area the unit resembles a gneissic granite), lies along the southeastern side of the district. Large intrusive serpentine bodies lie east of the Sykesville Formation.

The quartz-mica schists locally conta[illegible] gneissic bands of quartzite and quartz conglomerate. In the southern part of the district (fig. 5) the schists are sericitic; they contain [illegible] partly chloritized garnets and, locally, biotite. In general, schis[illegible] western part of the area (west of the chlorite-amphibole schist [illegible] are characterized by sericite, muscovite, and oligoclase, and those in the eastern part are characterized by sericite, chlorite, garnet, and biotite. The contact between these two varieties is gradational.

The country rock near the Patapsco mines in the northern part of the district (fig. 9) is quartz-biotite-chlorite schist, striking about N. 30° E. and dipping more or less vertically but locally contorted with many drag folds. Overbeck (1916, p. 154) states that the schist consists largely of fine-grained anhedral quartz, much biotite, muscovite, garnet, and magnetite: thus it is comparable to the quartz-mica schists in the southern part of the district.

The chlorite-amphibole schist and gneiss are in narrow belts that trend generally N. 35° E. For the most part, these belts lie within the quartz-mica schist, but between Sykesville and Eldersburg chlorite- amphibole schist is in gradational contact with the Sykesville Formation.

Although mapped as a single unit, the chlorite-amphibole schist consists of several types of mafic rocks, interbedded and in part gradational with one another. These include: (1) fairly coarse grained black amphibole gneiss with some associated chlorite, biotite, garnet, talc, zoisite, epidote, and vein quartz; (2) finer grained chlorite-amphibole schist, consisting of chlorite, biotite, hornblende, garnet, zoisite, and epidote, with local silicified and talcose shear zones generally parallel to the regional foliation; (3) hornblende gabbro gneiss composed of green uralite (Stose and Stose, 1946, p. 91) and greenish-white plagioclase partly altered to epidote, zoisite, and a sodic plagioclase; and (4) at the Springfield and Mineral Hill mines, thin bands of gray marble with crystals of actinolite and tremolite.

The ho nblende gabbro gneiss resembles orthogneiss and is probably the rock type studied by Jonas (1928), Stose and Stose (1946, p. 91), and Overbeck (1916, p. 154), who interpreted the mafic rock belts as one continuous metagabbro dike. The largest area of this gneissic metagabbro is in the central part ot the chlorite-amphibole schist belt cut by Morgan Run (fig. 5); it also occurs in the schist belt at the Patapsco mines near Finksburg.

The principal rock types on the Patapsco mine dumps are dark-gray to green hornblende schist and biotite schist, some containing disseminated magnetite. Overbeck (1916, p. 154) describes these rock types as follows:

> "A thin section of the biotite schist showed it to consist entirely of flakes of greenish biotite in an unaltered condition. There are several types of hornblende schist, one of which consists almost entirely of common hornblende with small amounts of magnetite and biotite; and another of which is made up of common hornblende, zoisite, some plagioclase feldspar, quartz, and much epidote which replaces the hornblende and is evidently a product of the decomposition of feldspar and hornblende.

"The rock appears to be derived from a basic igneous rock, and is probably a metagabbro."

Contacts between these rocks and the quartz-mica paraschist country rock are concealed in most places; they are apparently conformable, according to a few sharp contacts exposed near Morgan Run (figs. 5, 8).

Four small lenses of coarse-grained talc schist lie within the quartz-mica schist and chlorite-amphibole schist and gneiss. The rock consists of coarse-grained gray talc that apparently has replaced large grains of a bladed silicate mineral. Interstitial grains of grayish carbonate are probably siderite, for, where the rock is weathered, cavities left by leaching of the carbonate are encrusted with limonite. Coarse-grained magnetite is a common accessory mineral, and in the small body northwest of Eldersburg a few large grains of chalcopyrite are disseminated in the talc. The talc schist is coarsely foliated parallel to the regional foliation.

A dikelike body of bluish-black metaperiodotite forms a distinct unit within the chlorite-amphibole schist near Flohrville (fig. 5). Pyroxene and olivine partly altered to serpentine, apatite (?), and magnetite in numerous small equant grains, are the principal constituents. The metaperidotite is a fairly fine grained, dense, massive rock which has been foliated only locally. Contacts between metaperidotite and chlorite-amphibole schist, exposed during road building in 1957, are sharp. Coarse plates of chlorite or vermiculite lie along the planes of strong northeast-trending joints in the metaperidotite.

The coarse-grained granite-like Sykesville Formation (Jonas, 1928), (Hopson. 1964) extends from the Carroll-Baltimore County line about 2½ miles south of Finksburg southwestward through Sykesville and thence across Howard County (fig. 1). It is strongly foliated, and irregular tonguelike projections curve across the regional foliation in places. The Sykesville Formation is more mafic and more schistose near its boundaries. Along its contacts with adjacent rocks is a gradational zone several hundred feet wide of interbanded coarse quartz, plagioclase, muscovite gneiss and quartz-lean feldspathic biotite gneiss.

Schist fragments are common in the Sykesville Formation. In outcrops south of Piney Run and north of Sykesville, large angular blocks of quartzite and biotite schist are imbedded in a uniform quartz, feldspar, muscovite gneiss groundmass.

Small granite pegmatites are common between the Monroe prospect and Finksburg. Some pegmatite with miarolitic texture and cracks filled with zeolites was found on the Patapsco mine dumps but not in outcrop (Overbeck, 1916, p. 154).

The schists and gneisses in the Sykesville district apparently are the result of fairly low grade metamorphism and for the most part are transitional between the greenschist facies and the albite-epidote-amphibolite facies. The rocks are generally more coarse grained near the contacts with the Sykesville Formation in the southeastern part of the district.

The quartz-mica schists in the southern part of the district show evidence of retrogressive metamorphism by the presence of small relict garnets mantled with chlorite in a chlorite-muscovite-quartz groundmass. The talc schist may be the result of hydrothermal replacement of serpentines and may also represent retrogressive metamorphism.

The quartz-mica schists represent original sediments that have been regionally metamorphosed to their present composition. Parts of the chlorite-amphibole schist and gneiss such as the hornblende gneiss probably represent igneous intrusions, but other parts may represent original calcareous argillaceous sediments that have been recrystallized to a mafic composition by regional metamorphism and by hydrothermal solutions associated with mineralization. Thin marble layers containing actinolite, tremolite, and phlogopite at the Springfield mine, and the abundance of actinolite at the Mineral Hill mine are evidence that these rocks may have been derived largely from sediments. Local metamorphism of the chlorite-amphibole schist by the hydrothermal solutions deposited copper minerals is suggested by the fact that much of the gahnite, epidote, garnet, vein quartz, and coarsely crystalline actinolite, tremolite, and chlorite are localized in mineralized areas a'ong the magnetite-quartz-copper veins.

Mineral deposits

The copper-iron deposits of the Sykesville district are in veins mostly in the chlorite-amphibole schist and gneiss and in the talc schist. At the Mineral Hill deposit, quartz-mica schist forms one vein wall locally. At the open pit of the Springfield mine (fig. 5) the veins lie along the contact zone between chlorite-amphibole schist and quartz-mica schist. Characteristically, the veins are in nearly vertical or steeply dipping faults or in shear zones that strike parallel to the foliation and dip steeper than the wall rocks. Some of the veins occur singly; others are in clusters, either slightly in echelon or parallel. Some veins are traceable for more than 1,000 feet along the strike by old mines and prospects; others are reported to be short and lenticular. The veins are commonly 1 to 2 feet wide, but some thicken to as much as 24 feet. Well-defined ore shoots in the wide parts rake northward at the Patapsco and Mineral

Hill mines and southward at the Springfield mine, probably parallel to lineation in the adjacent wall rocks (fig. 5). Ore shoots at the Springfield mine are reported to have been 1,200 feet long and up to 24 feet wide.

Most of the veins are quartz-magnetite rock containing disseminated chalcopyrite and bornite and small bunches or scattered grains of sphalerite, carrollite, or linnaeite associated with gahnite, actinolite, zoisite and epidote, garnet, pyrite, chlorite, and talc; also locally, with fine-grained calcite, tremolite, and phlogopite. Large bunches, small bands, and lenses of nearly pure chalcopyrite, and less commonly bornite, occurred in places in the unoxidized parts of the veins. Much of the best ore probably was mined from these rich masses. A few veins (such as those of the Rice mine in Howard County, the Carroll mine, and the Monroe and Beasman prospects, figs. 6 and 7) contain mostly iron minerals with little copper except in sparse disseminations or very local bunches. Other veins consist of stringers and disseminations of copper sulfides that follow the foliation of the chlorite-amphibole schist; they contain only a little quartz, chlorite, talc, and silicate minerals as gangue. (Such veins were at the Patapsco mine in the tunnel workings, and one of the four parallel veins mined at Mineral Hill.) Stringers and disseminations of cobalt minerals (see p. 47) occurred in amphibole gneiss wall rock at the Mineral Hill mine.

Copper minerals are not reported at the Rice magnetite mine in Howard County (fig. 1). The Springfield mine, northeast of it, was opened as an iron mine in which the ore was specular hematite-quartz rock containing a little magnetite at the surface but apparently mostly magnetite-quartz at depth. Chalcopyrite became abundant at depths below 60 to 100 feet at the Springfield mine and 40 feet at the Carroll mine (fig. 5). Northeastward, copper minerals were found increasingly closer to the surface and magnetite became increasingly abundant at the surface. At the Patapsco mine in Finksburg both copper and magnetite were at the surface.

Springfield deposit.—At the main workings of the Springfield mine (fig. 5) the vein (or veins) strikes N. 25° E., and dips nearly vertically. The lenticular ore shoot rakes towards the southwest, possibly parallel to the wall rock lineation of 20 to 26 degrees. This vein was 20 to 24 feet wide in places at the surface and about 6 feet wide in the lower levels Whitney (1854, p. 319) described its attitude as follows:

> "It underlays 13° to the southeast for the first 60 feet, then descends nearly vertically for 10 feet, then underlays 8° to northwest for a depth of 100 feet, and from that point . . . it descends perpendicularly."

Shafts on a hill to the north (fig. 5) appear to be on a second echelon vein, or else the main vein makes a sharp double turn to connect the two workings. Two veins, called the "main" and "little" veins, are mentioned in an old report (Haeusser, Paynter, and Genth, 1864, p. 10). The walls of the veins are talc schist at the north shafts, quartz-mica schist on the west side of the open pit, and probably chlorite-amphibole schist along the east side of the open pit. The dumps contain much chlorite-amphibole schist and a little marble.

The ore at the surface is mainly specular hematite and magnetite in quartz impregnated with a little malachite and sooty chalcocite. This ore during the first and last years of operation was mined for its iron content. At a depth of 60 to 100 feet stringers of copper minerals were noted in the ore; they widened rapidly with depth until the veins contained large quantities of copper and a little cobalt and zinc.

The copper sulfides reportedly occur most abundantly along the upper sides of horses of barren rock that split the vein (Ansted, 1857). One such branch vein in the 270-foot level, raking at an angle of 45°, reportedly carried concentrations of chalcopyrite about 4 feet thick (Piggot, 1858, p. 264). Cobalt minerals are disseminated in discrete grains through the copper-iron ores of the adit dump (see p. 92).

Judging from material left on the dumps, the ore was predominantly magnetite at two shafts 500 feet north of the main mine. High-grade bornite ore, some in pure chunks at large as 3 pounds, was found on part of the dump from a shaft 700 feet north of the main mine. The dump material is mostly magnetite-quartz rock.

Whitney (1854, p. 319) gives the following ore grades at the main workings:

depth	*percent copper*
90-100 ft.	10-13
150-160 ft.	12-15
240 ft.	18-20

A grab sample (no. 153180) of typical ore from the adit dump was chemically analyzed by L. E. Reichen of the U. S. Geological Survey and found to contain 7.84 percent Cu, 0.22 percent Zn, and 28.91 percent Fe. Spectrographic analysis of this sample by Harry Bastron gave 0.19 percent cobalt, 0.027 percent nickel, and 1 ounce of silver per ton. Gold was looked for but not found.

Carroll deposit.–The copper ore at the Carroll mine (fig. 5) appears to be similar to that at the nearby Springfield mine but the quantity is very much less. The exposed veins are thin and are mostly magnetite, hematite, and quartz. A banded specular hematite-quartz rock is exposed at the surface and copper minerals occur in a small irregular ore shoot in the north part of the mine. Very few traces of copper can now be found on the brush-covered dumps.

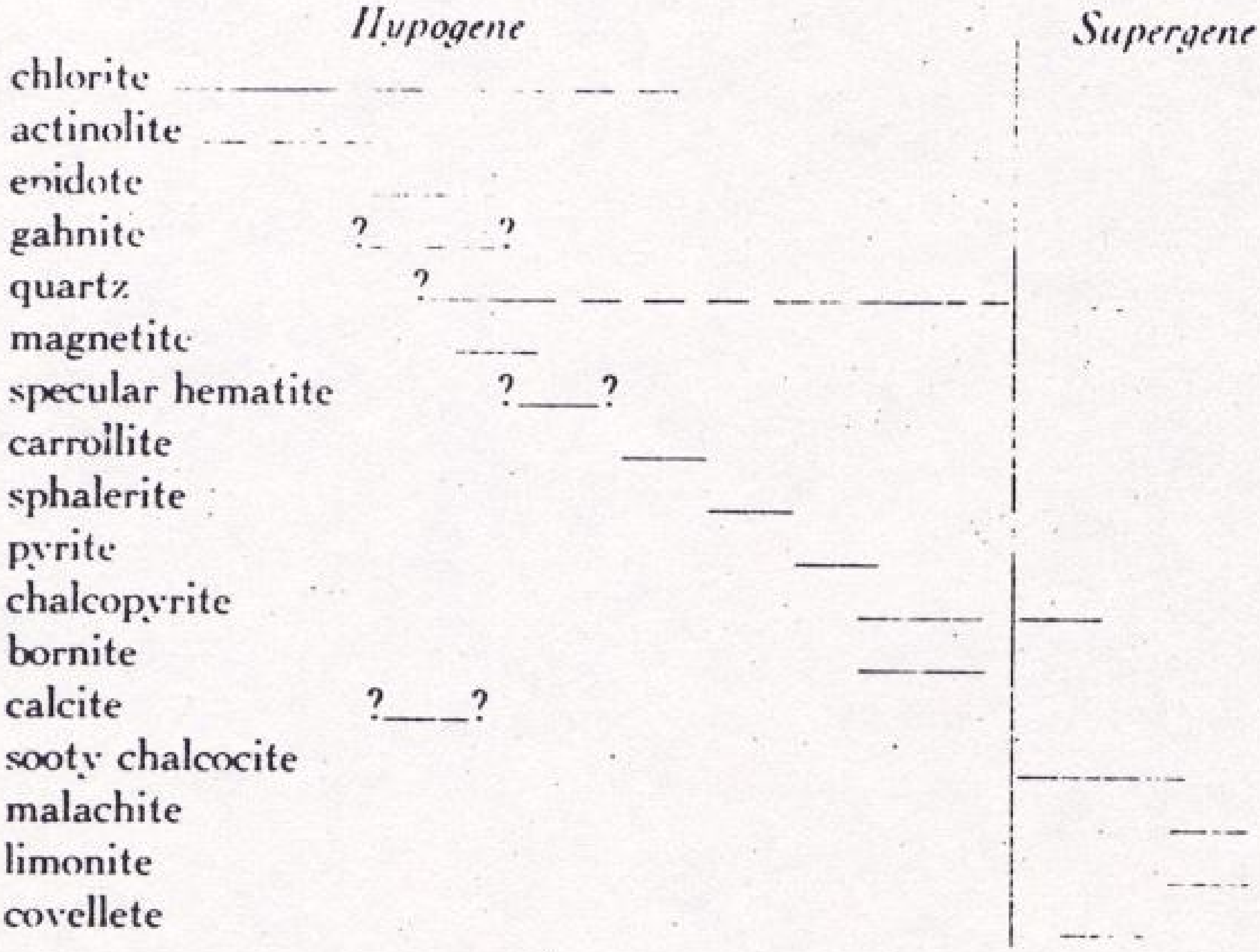
Mineral Hill deposit.—Several parallel veins are in a northeastward-trending mineralized zone that was worked for a length of 1,700 feet (fig. 8). Whitney (1854, p. 319) described four veins, of which three were being worked in 1854. Later reports mention only one vein, but the arrangement of present workings suggests that at least two and possibly three veins, occurring in echelon, were mined. The veins are in shear zones or faults dip 50° to 80° eastward, and are reported to be from 2 to 6 feet wide (Whitney, 1854, p. 319).

At the surface, three of the veins consist of quartz, magnetite, and specular hematite, with only a little copper and a few flakes of free gold. With depth, chalcopyrite and bornite are reported to become more abundant. One of these veins is exposed in the outcrops and shafts southwest of the main shaft (fig. 8). It is in a curved fault that has a quartz-mica schist hanging wall and a chlorite schist footwall; near the adit the vein cuts sharply across the foliation, but elsewhere it appears to be parallel to the foliation of the schists. Similar vein material is on the dumps of the "old" or pre-Revolutionary War workings.

The vein worked by the main inclined shaft is described as a shear zone impregnated with copper and cobalt sulfides. It is in chlorite-amphibole schist southwest of the shaft and talc schist northeast of the shaft. The shaft, inclined 50° eastward, follows this vein down dip for at least 370 feet (Williams, 1893, p. 123) and possibly over 400 feet (Singewald, 1911, p. 310). The mineralized shear zone appears to lie between the vein exposed southwest of the main shaft and the vein or veins mined by the "old" workings to the northeast. The main minerals in the vein are chalcopyrite and bornite, with which bunches of carrollite are locally associated. The ore is distributed in several northward-raking ore shoots, and magnetite and hematite are more abundant near the footwall of the vein (Overbeck, 1916, p. 161). Most of the mining in later years was probably from this vein, inasmuch as the large dump from the main inclined shaft is composed of material like that just described, and the descriptions of mining after 1860 mention operations in only one vein of this type.

The mineralogy of the deposit was studied by Overbeck (1916, p. 163). A similar study made by Heyl confirms Overbeck's paragenetic sequence for the ores with a few additions. The following paragenetic diagram follows the views of Overbeck for the most part with several modifications.

Paragenesis of the vein minerals of the Mineral Hill deposit



The ores are replacement veins in faults and shear zones. Mineralization took place after or very near the end of regional metamorphism as shown by the essentially undeformed minerals of the veins.

Oxidation of sulfides is shallow and may not have extended below the "old" or pre-Revolutionary War open cuts, which are about 30 feet deep.

Patapsco deposits.–Remington (1852, p. 3, 9) described seven veins ranging from about 3 to 12 feet in thickness. The veins were found at intervals on the large property over a distance of three-fourths of a mile. Ore had been mined from four of them. The location of three of the seven veins is shown on figure 9; they lie in echelon pattern along the northeastward trend of the mineralized belt.

Mineral assemblages in these veins include disseminations of chalcopyrite and pyrite; quartz and chalcopyrite; and magnetite, pyrite, bornite, chalcopyrite, and carrollite. Gahnite is present as a sparse early primary mineral. Most of the ore is partly oxidized to so ,ty chalcocite and other secondary minerals.

At the surface the ore vein at the Orchard mine (fig. 9) contained large quantities of gossan and pyrite, the latter coated with copper oxides at depth. The vein is 4 to 6 feet wide and lies between slickensided walls along a fault that strikes northeastward and dips steeply to the southeast. Near the engine shaft it is crossed by a smaller vein that strikes northward.

The vein at the Wildesen mine, reportedly 5 to 12 feet wide, strikes about N. 30° E. and dips 70° SE. It is essentially a pyrite-magnetite rock containing irregular concentrations of copper and more locally cobalt ores, some of which are rich. The vein lies in a well-defined fault, and a lenticular ore shoot rakes northward at about 40 degrees. Three large oval masses of nearly pure copper ore were found at depths of 50, 65, and 80 feet in the Wildesen vein; the largest was worth between $4,000 and $5,000 (Remington, 1852, p. 5).

The adit vein (fig. 9) was about 3 feet thick and included a 9-inch ore zone of copper minerals and pyrite.

Cobalt minerals

The copper-iron mines in the Sykesville district are notable for a small percentage of rare cobalt-bearing minerals associated with the ore. Discovered soon after 1850, these minerals excited much attention, especially at the Patapsco mines, and also some controversy among mineralogists. At the Springfield mine, branches of the copper-bearing vein contained ores that were 4 to 5 percent cobalt and nickel (Whitney, 1854, p. 319). A grab sample of typical disseminated copper-bearing rock from the dump of the Springfield mine, collected by the writers, contained nearly 0.2 percent cobalt, sufficient to be valued as a possible byproduct of the ores. The writers also found cobalt minerals at the Mineral Hill and Patapsco mines.

Cobalt minerals reported from the mines are linnaeite, siegenite, and carrollite—members of the linnaeite series—and a deep blue cobaltian variety of the zinc spinel gahnite. The linnaeite minerals are light steel-gray in color, with a faint pinkish hue and a metallic luster.

Linnaeite is basically the cobalt sulfide Co_3S_4, but nickel, copper, and iron can replace cobalt to some extent. Siegenite is the niccoliferous variety $(Co,Ni)_3S_4$. The cuprian variety carrollite, Co_2CuS_4, was first described in ore from the Patapsco mines in Carroll County (Faber, 1852). Other members of the linnaeite series, violarite and polydmite, have not been reported from the Sykesville mines.

Gradations between the varieties occur, so that there is no clear-cut distinction. Moreover, some of the material described and analyzed from the Sykesville mines proved to be intergrown with chalcopyrite or bornite (table 5, nos. 6, 7), so that published analyses may not represent accurately the composition of the linnaeite mineral. For this reason the copper content of carrollite varied considerably in reported analyses and there was some disagreement among mineralogists as to the reliability of carrollite (Smith and Brush, 1853; Genth, 1857; Shannon, 1926). Shannon noted that the iron content reported in earlier analyses was too small for the copper to be completely explained away as admixed chalcopyrite or bornite. He indicated instead that the unusually high copper content reported in earlier analyses was due to chalcocite replacing linnaeite along fractures and cubic cleavage lines (table 5, no. 12). The specimen he examined tended to break along the lines of chalcocite and looked megascopically like solid chalcocite.

If the analyses recorded in table 5 are representative of the cobalt minerals from each of the mines, it is notable that the material from the Springfield mine carries a small percentage of copper (carrollite) and that from Mineral Hill is nickeliferous (siegenite). Material from the Patapsco mines, although consistently very rich in copper, is reportedly linnaeite replaced by chalcocite. Recent spectrographic analyses of pure grains of the cobalt mineral from the Springfield mine indicate that it contains sufficient copper for carrollite (Howard Jaffe, oral communication, 1956).

At the Mineral Hill mine, Shannon (1926) found in the stone ruins of an old ore house a pile of copper ore that had apparently been sorted when the mine was active. Every piece contained cobalt minerals. In the best specimens, bands as wide as one centimeter of reddish-gray carrollite or siegenite were interlayered with bands of quartz and magnetite.

According to Overbeck (1916, p. 155), "carrollite" occurs at the Patapsco mines largely in schist near its contact with pegmatite. The superintendent of the mines reported that in the Wildesen mine cobalt increased steadily downward and was at first considered iron ore. A vein about an inch thick of "black oxide of copper" that was encountered at a depth of about 70 feet in the Wildesen shaft proved to be cobalt-rich and widened to 6 inches (Remington, 1852, p. 5).

Cobaltiferous gahnite from the Sykesville mines was described and analyzed by Shannon (1923). It is in octahedral crystals as much as 5 mm in diameter and granular masses of smaller crystals several centimeters in diameter. It is indigo blue and occurs in veins of glassy quartz

TABLE 5. Published analyses of cobalt minerals from copper mines in the Sykesville district, Carroll County, Md.

	1	2	3	4	5	6	7	8	9	10	11	12
Source	Patapsco mines	Patapsco mines	Patapsco mines	Patapsco mines	Patapsco mines	Mineral Hill mine	Mineral Hill mine	Mineral Hill mine	Spring-field mine	Spring-field mine	Carroll County	Patapsco mines
Analyst's description	carrollite	copper linnae-ite	copper linnae-ite	copper linnae-ite	carrollite	seigenite with 19.49 % admixed chalcopyrite		carrollite	copper linnaeite	copper linnaeite	linnae-ite	linnaeite partly re-placed by chalcocite
Co	28.50	37.25	38.21	37.65	38.70	25.69	50.76[3]	36.08	444.4	48.63	48.70	42.42
Ni	1.50	1.54[1]	1.54[1]	1.54[1]	1.70	29.56		7.65	trace	trace	4.75	trace
Cu	32.99	17.48	17.79	19.18	17.55	2.23	3.63	9.98	6.50	4.43	2.40	15.43
Fe	5.51	1.26	1.55	1.40	0.46	1.96	3.20	2.25	4.57	3.55	2.36	0.28
As	1.82	trace	trace	trace	...	...	...	...	...	...	...	...
S	27.04	41.93	40.94	40.99	41.71	39.70[2]	41.15	41.89	44.89	43.56	41.70	41.34
Insol.	2.14	...	...	...	0.07	0.45	1.26	0.50	...	0.68	0.40	0.53
TOTAL	99.30	99.46	100.03	100.76	100.18	99.59	100.00	98.35	100.40	100.85	100.31	100.00

1\. Faber (1852)
2—4. Smith and Brush (1853)
5—7. Genth (1857)
8—12. Shannon (1926)

[1] Only one estimate of nickel made.
[2] Some was accidentally lost.
[3] From the loss; proportions about the same as in 6.

as wide as 10 centimeters, enclosed in fine-grained micaceous schist. In one specimen from Mineral Hill the gahnite was in streaks parallel to the walls of the veins. At the Patapsco and Mineral Hill mines it is intergrown with minor amounts of magnetite and chalcopyrite. Gahnite from the Springfield mine is more greenish and less deeply colored than specimens from the other mines. A sample from Mineral Hill contained 1.18 percent cobalt oxide.

Booth (1852) described a thin rose-colored coating on serpentine from the Patapsco mines as a hydrous cobalt carbonate, and he named it "remingtonite" for the mine superintendent, Edward Remington. The mineral was never analyzed, however, and Shannon (1924) later suggested that the material described was a cobalt-stained serpentine or a cobalt equivalent of the nickel silicate garnierite. In a thorough search of the mine area Shannon was unable to find more of the same material; however, a pinkish cobaltiferous serpentine marginal to a carrollite-chalcopyrite-bornite veinlet was found at the Springfield mine by the writers.

Paragenesis

The mineralogy and sequence of deposition of the minerals of the copper veins, particularly those of the Patapsco and Mineral Hill mines, were described by Overbeck (1916), and unusual minerals in the ores were described by Shannon (1923, 1924, 1926). Overbeck noted that most of the silicate minerals, including hornblende, epidote, garnet, and the spinel gahnite, were deposited first. Magnetite in crystals and veinlets and then specular hematite were deposited after these minerals, followed by carrollite (or linnaeite) in irregular grains or octahedral crystals, black marmatitic sphalerite, and then chalcopyrite and bornite in irregular primary intergrowths. Deposition of quartz started with the silicates and continued through the sulfide period. Some chalcocite and covellite, probably supergene, replaced hypogene sulfides.

Most of Overbeck's findings were confirmed by Heyl's restudy of the ores from samples available at all the mines, including the Springfield (not studied by Overbeck). Some additions to and variations from Overbeck's work are noted below.

At the Patapsco mines some green actinolite appears to be contemporaneous with the sulfides. At the Springfield mine tremolite, actinolite, zoisite, and phlogopite are common in the marble layers as silicate minerals deposited prior to the sulfides but closely associated with them. Zoisite and actinolite of the same relative age are abundant in the

Mineral Hill mine ores. Sparse flakes of molybdenite occur as an early sulfide at the Springfield mine. Pyrite is locally abundant at all the mines as an early sulfide that followed the magnetite and hematite but preceded the copper sulfides. The quartz-hematite and quartz-magnetite layers are interlayered and some of the magnetite is in euhedral subrounded crystals imbedded in quartz and probably replacing it. The copper sulfides in the disseminated ores are interstitial to the iron minerals and form crosscutting veins. Late thin glassy to smoky quartz veins containing masses of copper sulfides up to an inch across cut the iron minerals. Late veins of coarse-grained white calcite cut the sulfides at the northern shafts of the Springfield mine. At the Springfield mine much of the chalcopyrite surrounds bornite, rimming it in places and forming distinct veinlets, indicating that here, at least, chalcopyrite continued to be deposited after deposition of bornite ceased.

MINE DESCRIPTIONS

Springfield mine

The Springfield mine is about half a mile northwest of Sykesville, Carroll County (fig. 5). Also known as Mr. Tyson's mine and the Sykesville mine, it was opened by Isaac Tyson, Jr., in 1849 as an iron mine. With depth it developed into a copper mine and was worked as such profitably from 1852 until 1869, when, unable to renew their lease, the Tyson company mined the pillars and allowed it to cave. About 1880 the old Springfield mine and the nearby Carroll mine were reopened briefly as the Springfield iron mine; however, most of the work seems to have been done at the Carroll mine. In 1916 the main Springfield deposit was worked by a large open cut to produce specular hematite-quartz ore. The product was used in Baltimore by the Shawinigan Electroproducts Co. for the manufacture of ferrosilicon (Singewald, 1946, p. 159).

A sample from an outcrop of specular hematite-quartz rock at the mine was analyzed as follows (Singewald, 1911, p. 309):

Fe	46.77 percent	Mn	0.18 percent
SiO_2	30.66	P	0.11
Al_2O_3	1.89	S	0.05
		Ign. Loss	0.43

Several old mining reports reflect the progress of operations at the Springfield mine during its 20 years of activity. In 1853 the main shaft was 210 feet deep, with levels at 96 feet and 126 feet, each 90 feet long, connected by a winze. Stopes from the 126-foot level were 30 feet long and 30 feet high. An adit 66 feet below the surface and 500 feet long provided drainage and a means of removing the ore (Jackson, 1853b; Whitney, 1854, p. 319). By 1857 there were four levels, some additional stopes, and a new shaft, inclined at an angle of 45 degrees. This shaft apparently is the one several hundred feet north of the main shaft and sunk on a newly leased deposit of bornite (Piggot, 1858). Tyson (1862, p. 67) reported that by 1862 the main shaft was 700 feet deep, and Williams (1893, p. 113) that it finally reached a length of 1,400 feet on the incline.

The surface workings visible in 1958 are shown in figure 5. The 1916 work, which left an open cut 350 feet long, 50 feet wide, and more than 20 feet deep, obscured much of the surface evidence of the location of the main copper shaft. This shaft was apparently in or just northeast of the northeastern part of the open cut. Remnants of the caved adit can be traced trending N. 70° E. to a small stream. The large, main dump is northeast of the open cut, and an adit dump lies in the valley east of the main dump. Copper is evident in the main dump, abundant in the adit dump, and absent in a high brush-covered dump west of the open cut. Cobalt minerals are present on the adit dump. North of the adit dump are two shallow prospect shafts and a pit.

About 500 feet north of the main shaft are two additional shafts, about 20 feet apart in a northeastward line, and several shallow prospect pits. Banded magnetite-quartz rock, talc schist, and a little chalcopyrite are the dump materials. About 200 feet farther north along the top of the hill is a filled shaft and a dump estimated to contain 1,000-2,000 tons of rock, most of which is fine- to coarse-grained magnetite-quartz rock. On one part of the dump is some high-grade bornite ore, some in pure chunks as large as 3 pounds, identifying this as the bornite shaft reported by Piggot (1858). Elsewhere on the dump a little chalcopyrite was found. Still farther to the northeast, a caved drainage adit in barren rock leads southwestward from Piney Run for an unknown distance into the hillside.

CARROLL MINE

The Carroll, or New Burra, copper mine is northeast of the Springfield mine and across Piney Run from it (fig. 5). The mine was small and not important as a copper producer, but a small- to fair-sized tonnage of iron ore may have been mined. It reportedly was operated briefly in the 1840's by the Carroll Co., again in the 1850's, and finally in the 1860's by the New Burra Co. It may be the "Florence mine" near Sykesville, mentioned by some writers. When reworked for magnetite in 1880 it was included under the name "Springfield mines."

In 1854 the Carroll mine (fig. 5) consisted of (from northeast to southwest) a main shaft 72 feet deep, an engine shaft 150 feet deep, and an adit 210 feet long, which extended northeastward from Piney Run to intersect the engine shaft at a depth of 75 feet (Ansted, 1857, p. 244). The engine shaft was later deepened to 240 feet. In 1864 the New Burra Co. sank a trial shaft about 40 feet southwest of the main shaft and found copper ore at a depth of 42 feet (Martin and Vivian, 1865, p. 7). A level was started northward from the engine shaft 135 feet below the surface to intersect the copper ore shoot, but probably was not completed.

When the writers visited the mine, the caved adit, which trends N. 30° E., was the southwesternmost of six openings. The engine shaft on top of the hill north of the adit, is surrounded by between 5,000 and 10,000 tons of dump material. A deep hole north of the shaft apparently is caused by stopes caving to the surface. A quartz-magnetite vein exposed on the north wall of this caved hole is 1 to 3 feet thick, strikes N. 20° E., and dips 75° SE. The wall rocks are chlorite and talc schist. Northeast of this cave-in is a fourth opening, a small shaft that may date from the 1880 period when the mine produced iron ore. Two shafts about 150 feet north of the engine shaft are apparently the New Burra copper shaft and the main Carroll shaft. The dumps from these shafts contain much magnetite, epidote, and garnet, and only a trace of copper minerals.

Partial analyses of two samples of magnetite ore from the Carroll mine when it was worked in 1880 gave these results (Benton, 1886):

Metallic iron	64.44 percent	64.85 percent
Phosphorus	0.243	0.251

The first sample was obtained at the mouth of a reopened shaft (probably the northernmost or old Carroll shaft). A 10-ton pile of ore from which it was taken came from near the bottom of the shaft and was considered representative of the entire 2-foot thickness of the deposit, including some poor ore. The second sample was taken across the 2-foot thickness at the bottom of the shaft, at a depth of about 100 feet.

MONROE PROSPECT

About 1850 the Monroe property 1½ miles north of Eldersburg, Carroll County (fig. 5) was leased, and later it was purchased, by the Tysons. Although an ore vein was extensively prospected, no ore was produced (Singewald, 1911, p. 310).

The Monroe prospect consists of a series of shallow shafts and pits trending northeastward along a vein of magnetite-quartz rock (fig. 6). An adit, now caved, extended about 150 feet southeastward to the largest shaft. The adit dump contains some magnetite and pyrite; the shaft dump contains magnetite and sparse copper minerals, including chalcopyrite, bornite, azurite, malachite, and tenorite. Some copper minerals also were found on the dumps of three pits several hundred feet to the northeast.

BEASMAN PROSPECT

The Beasman prospect comprises at least 3 shafts, an adit, and several prospect pits on both sides of State highway 32 about a mile northeast of the Monroe prospect (figs. 5 and 7). Some of the workings were probably destroyed when the highway was built in 1954. The property was prospected in 1865 by a New York company, but no ore was shipped (Singewald, 1911, p. 310).

Magnetite-quartz-hematite rock and chlorite schist constitute most of the dump material at the Beasman prospect. Pyrite is abundant on the dump just west of route 32 and on the adit dump south of Liberty Lake reservoir (fig. 7). A little chalcopyrite was found on two of the dumps.

MINERAL HILL MINE

The Mineral Hill mine is three-fourths of a mile southwest of Louisville, Carroll County, immediately north of, and partly flooded by, the Morgan Run branch of Liberty Lake reservoir (figs. 5 and 8). One of the oldest copper mines in Maryland, it was opened soon after 1748 by British interests, and a small smelting furnace was built about 1½ miles northeast of it across the North Branch of the Patapsco River in an area known as Deer Park. In 1760, this furnace, called the "Fountain Copper Works," was treating ore from both the Mineral Hill and Liberty mines (Robinson, 1939, p. 24). The mining operations we . large for this early period as shown by the open cut of the "old" workings from which thousands of tons of ore and waste were mined. At the outbreak of the American Revolution the mine was closed, the owners returned to England, and the property was confiscated. In the 1780's ore from the Libert mine was treated a Deer-Park copper works (presumably the same furnace), but the i no record that the Mineral Hill mine was being worked at that time. A copper mine 22 miles from Baltimore near Deer Park, once called "Scott's mine," was advertised "to let" in 1786 and again in 1791 (Robinson, 1939, p. 25); the location suggests that this was the Mineral Hill mine.

In 1849 the mine was reopened by Isaac Tyson, Jr. According to Singewald (1911, p. 310-311), a lease was obtained by John Triplett and John Williams, who had worked for Tyson in his Baltimore County chromite mines, and they opened the old mine, then sold out to Tyson. The mine was worked almost continuously until about 1890. As many as 100 workers were employed at times after 1860 (Singewald, 1946), but at other times the operations were on a very small scale. In 1861 the Tyson interests were transferred to the Mineral Hill Mining Co. of Baltimore, which encountered financial difficulties and sold the mine back to Tyson's heirs, apparently after 1880. Williams (1893, p. 113) states that in 1890 the mine was "temporarily closed"; however, no record of further production is available.

Surface workings of the Mineral Hill mine are shown on figure 8. The large open cut in the northeastern part of the mine area was worked before the Revolutionary War. A shaft southwest of the open cut and another northeast of it probably date from the later period of mining, but the main workings between 1849 and 1890 were those in the southwestern part of the map area.

Records of the underground workings are somewhat confusing. In 1854 the mine consisted of three shafts 250 feet 160 feet, and 90 feet deep, plus levels at 100 feet and 160 feet. The 250-foot shaft later caved.* In 1860 an adit 450 feet long was driven into the hill to meet an inclined shaft at a vertical depth of 140 feet. In 1888 this main shaft, inclined 50°, was reportedly 370 feet deep on the vein with levels down the incline at 60, 120, and 180 feet and a connecting adit 190 feet long (probably the unstoped southern part of the 450-foot adit) to Morgan's Run (Williams, 1892, p. 123). Singewald (1911, p. 310f) states that the main shaft was over 400 feet deep, so that the actual maximum depth is not certain. The main level apparently is the adit level which is about 140 feet vertically below the shaft collar. Most of the stoping was probably done above this level, and nowhere are mentioned either drifts or stopes below the level. The sparsity of mineralized rock on the main shaft dump suggests that much excavation was done in nearly barren rock. Bulldozing of the eastern part of the dump in 1965 exposed much copper-bearing rock in the dump.

In the 1950's part of the mine was flooded through the drainage adit by the Liberty Lake reservoir.

*Overbeck, R. M., 1915, The copper ores in Maryland: Johns Hopkins Univ. Ph.D. dissertation, p. 4.

PATAPSCO MINES

The Patapsco mines are on both sides of U. S. Highway 140 and State highway 526 about three-fourths of a mile east of Finksburg (fig. 9). They are the northeasternmost copper-iron mines in the Sykesville district.

The Patapsco Mining Co., under the management of Edward Remington, opened the southern or Wildesen mine in 1849 and the northern or Orchard mine in 1851. After cobalt and nickel were identified in the ore in 1852, the company reorganized as the Patapsco Copper and Cobalt Mining Co. A cobalt smelting furnace was erected along the Patapsco River but never used. The mines were closed in 1858. From 1860 to 1865 one or both of them were worked by the Maryland Copper Co. (of Baltimore). Magnetite was produced from one of the mines in the early 1880's.

The Wildesen mine (fig. 9) is about 200 yards south of Maryland highway 526. In 1852 it consisted of three shafts 35, 110, and 160 feet deep; a drift about 140 feet long connecting the shafts at an average depth of 110 feet; and a crosscut 15 feet long at the bottom of the deepest shaft (Remington, 1852).

The Orchard mine is northeast of the Wildesen, between Md. highway 526 and U. S. route 140. Three shafts, and possibly four, are included. A house on the south side of 526 is on the site of one of the shafts. In 1852 the mine consisted of only two shafts 175 feet apart, one 110 feet and the other 116 feet deep. They were connected by a drift at a depth of about 60 feet. At the bottom of the northern or engine shaft a second level had been driven about 15 feet northeastward and 30 feet southwestward. An adit from the Patapsco River about a quarter of a mile northeast of the shafts was 600 feet long.

By 1865 the Orchard mine reportedly was 365 feet deep with levels about 600 feet long at depths of 100 and 160 feet (Singewald, 1911, p. 311). The relationship between these workings and those described in the Patapsco Co.'s prospectus (Remington, 1852) are not clear.

RICE MAGNETITE MINE

The Rice mine is in Howard County, on the west side of a county road about 4 miles southwest of Sykesville (fig. 1). It was worked by James Tyson, probably in the 1850's or 1860's, on land that belonged to John Wayman. Singewald (1911, p. 319) reports that an opening 150 feet by 30 feet is so filled with rubbish that the depth cannot be ascertained. The magnetite deposit occurs in a small area of chlorite schist surrounded by granite.

FORSYTHE LIMONITE MINE

The Forsythe mine was just east of the Rice mine on the east side of a county road. Soft yellow limonite occurs in green chlorite schist, probably as a gossan deposit. Ore was mined and shipped to Baltimore in the early 1850's, when the property belonged to Andrew Ellicott. The mine reportedly consisted of three shafts and a drainage tunnel, all of which caved because of inadequate timbering (Singewald, 1911, p. 318). The openings were filled, and now the mining site is cultivated farm land.

Geology

The Bare Hills district is small, covering less than 1 square mile within the suburbs of greater Baltimore about 1 mile northwest of Mt. Washington, Baltimore County (fig. 1). It is in the northeastern corner of an extensive area which Jonas, Knopf, and others (1925) mapped as undifferentiated gabbro and metagabbro intruding oligoclase-mica schist.

The gabbroic rocks of the area are described in detail by Williams (1886) and by Knopf and Jonas (1929, p. 107-114.) In the Bare Hills district they are predominantly hornblende gneiss, which is considered to be altered hypersthene gabbro. Knopf and Jonas (1929, p. 111-112) described the rock as follows:

> "The resultant constituents of a meta-gabbro are a clear feldspar (oligoclase), quartz, uralite, epidote, zoisite, and sometimes biotite and kaolinite. In the hand specimen the meta-gabbro is a rock of striking appearance composed of greenish-black hornblende with a satiny luster and white opaque feldspar and sometimes quartz. Surface weathering results in the removal of the feldspar thereby giving a pitted appearance to the rock. Such a rock possesses a secondary banding produced by the development of hornblende and may be called a hornblende gneiss. This banding or foliation . . . usually dips northwest."

The rocks that crop out at the Bare Hills copper mine (fig. 10) are mostly hornblende gneiss and hornblende-chlorite schist. Northeast of the mine are several outcrops of chloritic paragneiss with feldspar porphyroblasts. A garnet-bearing quartz-feldspar paragneiss with accessory magnetite and pegmatite stringers is exposed in a prospect pit nearby and also crops out farther to the east; foliation that probably parallels bedding strikes N. 30° E. and dips SE., and a lineation plunges at a low angle toward the southwest.

About a quarter of a mile north of the copper mine is an intrusive mass of serpentinite from which chromite was once mined, and smaller intrusions of serpentinite lie south and southwest of the mine. Baltimore Gneiss of Precambrian age is the main rock type farther to the east across Jones Falls; it is separated from the rocks on the west side of the valley by a north-striking fault.

The rocks of the district are coarse grained and apparently are in the albite-epidote-amphibolite facies of intermediate metamorphic grade. They are of somewhat higher metamorphic grade than those of the Sykesville district, as shown by an abundance of hornblende, plagioclase, anthophyllite and cummingtonite, epidote and zoisite, red garnets, magnetite, and chlorite. A marked increase of amphiboles at the expense of chlorite in the main ore body at the Bare Hills mine suggests that local metasomatic alteration halos were developed in the wall rock by the ore-bearing solutions at temperatures higher than those produced by regional metamorphism.

MINERAL DEPOSITS

The ore at the Bare Hills mine was high grade, consisting of chalcopyrite, some bornite, and a little primary chalcocite. It occurred in a vein or lens that may have been nearly solid massive sulfide intermingled with coarse-grained magnetite. A thick envelope consisting of hornblende, much magnetite, coarse silicates such as anthophyllite, cummingtonite, albite, and zoisite, and some bornite and chalcopyrite, apparently surrounded the copper ores, fading into hornblende schist both along and across the strike. The lens or vein of massive sulfide was reportedly 4 to 8 feet wide, probably trending N. 70° E. and dipping about 45° SE. The ore shoot raked southeastward down the dip of the vein (fig. 10, section). In the lower workings the rake seems to have been southwestward.

The presence of thin seams of magnetite in hornblende schist at prospects northeast of the mine for about half a mile (fig. 10) suggests that the Bare Hills deposit may be one lens in a zone of magnetite-rich lenses similar to those in the Sykesville district. The Bare Hills deposit differs from the Sykesville copper-iron deposits in that it was enveloped in coarse-grained hornblende-magnetite-anthophyllite rock and contained no hematite and apparently no cobalt minerals. The mineralogic relationships suggest that the ore deposit originated at higher temperatures than the Sykesville deposits.

Paragenesis.—The general order of deposition of the minerals of the ore deposit, beginning with the wallrock marble and silicate minerals and ending with the sulfides, is given on . (1) Calcite marble remnants which occur throughout the hornblende schist appear to be the earliest gangue mineral; then (2) pearly to silkly plates of anthophyllite, cummingtonite, and (or) wollastonite. (3) Next youngest are apparently tremolite and actinolite, but these may be younger than (4) hornblende, which is the principal silicate. (5) Small quantities of sodic plagioclase follow, then (6) pale-green crystals of zoisite and darker green epidote, then (7) much bright green-black chlorite and a little sodic plagioclase. In places, (8) sericite is deposited as an abundant late silicate. (9) Quartz, where seen, is fairly late; some of the replacement variety is glassy and granular and pre-magnetite, and some, in crosscutting quartz veins with sulfides, is definitely post-magnetite.

Paragenesis of the Bare Hills copper deposits

Calcite (recrystallized dolomitic marble)	—— vein calcite ——
Anthophyllite, cummingtonite, and (or) wollastonite	——
Tremolite and actinolite	?—? — —?
Hornblende	——
Sodic plagioclase	—— ?——?
Zoisite and epidote	——
Chlorite	? — — ? — — ? — ——— — — ?
Sericite	?—?
Quartz	?— — ? — —
Magnetite	——
Chalcopyrite	— —
Pyrite	—?—
Bornite	—
Chalcocite	—
Marmatitic sphalerite (?)	—
Periods of fracturing	? x x x ? x x x x x x

The ore minerals are next. (10) Magnetite is in coarse crystalline masses that replace the schistose wall rocks mostly parallel to the foliation, and also as discrete octahedral crystals up to a quarter of an inch in diameter in tremolite (?)-sericite schist. (11) Chalcopyrite, replacing and transecting magnetite, is associated with considerable euhedral (cubic) pyrite and late quartz veins and quartz replacement masses. Most of it is younger than the quartz with which it is associated but a few veins of magnetite and chalcopyrite cut replacement quartz. (12) A little fine-grained bornite, and steel-gray chalcocite in actinolite schist, are definitely younger than both the pyrite and chalcopyrite. (13) A little black sphalerite (?) apparently is the youngest sulfide. In one sample post-sulfide fracturing was noted.

The only secondary minerals noted are limonite, malachite stains and coatings, gypsum needles, and a bright-green mineral—possibly a copper arsenate such as conichalcite. A little native copper was reportedly found at the mine (New London Copper Mining Company of Frederick County, Md., 1864). Garnet, talc, stilbite, and laumontite are also reported from the deposits (Ostrander and Price, 1940, p. 27), but were not noted by the authors.

The Bare Hills mine (also known as the Vernon or Smith Avenue mine) is the only copper mine in the Bare Hills district. The main shaft and large dumps are just north of Smith Avenue near a sharp curve in the road (fig. 10); numerous prospect pits and trenches are in the wooded area east-northeast of the mine within a distance of about 600 yards. Most active during the 1860's, the Bare Hills mine reportedly produced more than $1,700,000-worth of copper (see p. 20 for details. In 1957 the main shaft was filled and the dumps were being leveled in preparation for a suburban housing development.

Copper was discovered at Bare Hills about 1839 on the land of Thomas B. Watts, and the deposit was examined by the Maryland State Geologist, Joseph Ducatel (1840, p. 40), who recommended further exploratory work. The deposit was mined fairly continuously for more than 45 years after 1845 but was the subject of lengthy litigation concerning conflicting leases and so operations suffered from changes in ownership. By 1855 a small irregular shaft was 350 feet deep. In 1858 William H. Keener purchased a controlling interest in the mine, and in 1864 he became president of the Bare Hills Copper Mining Co., which had been incorporated 4 years previously. The shaft was improved, additional equipment installed, and from 1864 until 1868 mining was on a larger scale. A flood late in 1868 halted operations for a while, after which mining continued intermittently until 1889. After 1873 the Bare Hills Co. was succeeded by the Vernon Mining Co. In the late 1890's a new company was formed and 6 carloads of ore were produced. In 1905 and 1908 attempts were made to operate the mine, but it probably was not even dewatered.

The main shaft of the Bare Hills mine slopes southward at an angle of 45 degrees and is 832 or 900 feet deep down the incline (fig. 10). Numerous drifts and stopes extend from it along the vein. The extent of the lower workings is not known. According to Williams (1893, p. 114), "considerable copper" remained at the bottom of the inclined shaft when the mine was closed in 1889. Weed (1911, p. 65) reported that there were also two ventilation shafts.

Numerous prospect pits and trenches in the wooded area east-northeast of the mine show no indication of copper mineralization. The dump of a prospect adit 1,000 feet northeast of the main shaft contains a little magnetite but no copper minerals. One small pit southwest of the mine on the other side of Smith Avenue may have been a prospect hole, but construction of a golf course in this area has removed all traces of any other prospecting that may have been done.

None of the mining districts contain known ore reserves. All of the ore deposits are relatively small compared to most of the copper, iron, zinc, lead, and barite deposits that are currently mined. The Bare Hills, Springfield, New London, Mineral Hill, Liberty, and Dolly Hyde mines had profitable periods of operation, but the over-all history of these mines showed that mining costs usually exceeded the value of the ore produced.

A few of the mines closed with ore probably remaining. Williams (1893, p. 114) stated that the Bare Hills mine when it was closed in 1889 "showed considerable copper at the bottom of the shaft." Similarly he said (p. 112) that the Mineral Hill mine has "considerable promise of ore." Others, such as the Springfield and New London mines, were closed during profitable operation and may have ore remaining. Some ore probably also remains at the Liberty mine, and parts of the present wall rocks contain disseminations of copper minerals that might be mineable along with the higher grade ore shoots. The whole 1400 foot long marble lense might be explored to see if it all might be mineable by mass production open-cut methods.

The Linganore district is the most favorable of the three districts for prospecting and possible future mining. Undiscovered ore bodies probably exist, and, judging from the size of the Liberty mine deposit, some could be large enough to be mined efficiently by modern large-scale methods. Geochemical prospecting and photogeologic mapping might be useful in locating areas of black manganiferous soil or of metal concentrations which form halos over many of the mineralized areas. The rocks of the district can be diamond drilled with good core recovery and low bit losses.

The copper ores of this district are lean in pyrite and would be particularly amenable to low-cost milling; furthermore, they carry silver and gold as byproducts. If lead deposits large enough to be commercially mined exist in the district, they probably contain recoverable amounts of silver, copper, and zinc. Because the gray or colorless sphalerite in the district is very difficult to identify, zinc deposits may have been overlooked in past prospecting. Several hundred tons of oxidized zinc ores are known to have been produced formerly.

Ore deposits that are known in the Sykesville district are relatively small vein deposits, and others that may exist are not likely to be large. Cobalt and zinc minerals associated with the ore minerals could be valuable byproducts of mining for copper and siliceous iron ores. The Springfield mine, however, may be caved beyond recovery, and parts of the Patapsco and Mineral Hill mines are flooded by Liberty Lake reservoir. Profitable mining operations would depend on the discovery of new deposits and would probably require beneficiation of the ore from several small mines at a central mill. How readily the ore could be milled is not known. The occurrence of several of the minerals, including carrollite, in discrete grains might aid in the separation and concentration of the various products. The nearness of the district to iron and copper furnaces at Baltimore is a distinct advantage.

Two other zones of mineralized veins parallel to the belt that contains the Sykesville mines were reported by Ansted (1857). These are not known to have been prospected. The talc schist lens near Johnsville, west of the main ore zone (fig. 5), contains a little chalcopyrite and magnetite. Perhaps, then, these areas are worth further investigation.

The Bare Hills mine area is rapidly becoming a part of the Baltimore suburbs, and thei o possibility of future mining in that immediate vicinity.

References

Ansted, D. T., 1857, On some copper lodes near Sykesville in Maryland: Geol. Soc. London Quart. Jour., v. 13, p. 243-245.

Bangs, Herbert, 1946, The A. A. Roop copper mine: Maryland, v. 16, no. 3, p. 61-63.

Benton, E. R., 1886, Notes on samples of iron ore collected in Maryland: U. S. 10th Census, v. 15, p. 245-260.

Booth, J. C., 1852, On remingtonite, a new cobalt mineral: Am. Jour. Sci., 2d ser., v. 14, p. 48.

Butler, B. S., and McCaskey, H. D., 1915, Copper ores of the New London mine: Am. Inst. Mining Engineers Trans., v. 49, p. 284-291.

Cloos, Ernst, and Broedel, C. H., 1940, Geologic map of Howard County: Md. Geol. Survey.

Cloos, Ernst, and Cooke, C. Wythe, 1953, Geologic Map of Montgomery County and the District of Columbia: Maryland Geol. Survey.

Dieffenbach, Otto, 1858, Bemerkungen ueber den Kupferbergbau in den Vereinigten Staaten von Nord-Amerika: Berg-und Hutt. Zeit., p. 66-68, Leipzig.

Ducatel, J. T., 1840, Annual report of the geologist of Maryland, 1839, p. 22-23, 40.

——, 1841, Annual report of the geologist of Maryland, 1840, p. 45-46.

Ducatel, J. T., and Alexander, J. H., 1834, Report on a projected geological and topographical survey of the State of Maryland: Am. Jour. Sci., v. 27, no. 1, P. 1-38

Engineering and Mining Journal, 1879, Editorial: Eng. Mining Jour., v. 28, p. 499.

——, 1899, Note: Eng. Mining Jour., v. 67, p. 213.

——, 1901, Note: Eng. Mining Jour., v. 72, p. 613.

Faber, W. L., 1852, On carrollite, a new cobalt mineral: Am. Jour. Sci., 2d ser., v. 13, p. 418-419.

Frazer, Persifor, 1881, Some copper deposits of Carroll County, Maryland: Am. Inst. Mining Engineers Trans., v. 9, p. 33-40, maps.

Genth, F. A., 1857, Contributions to mineralogy: Am. Jour. Sci., 2d ser., v. 23, p. 418-419.

Haeusser, Ernest, Paynter, Thomas, and Genth, F. A., 1864, Reports on the New London copper mine, *in* Prospectus of the New London Copper Mining Co. of Frederick County, Md.: Philadelphia, Pa., 22 p.

Hopson, C. A., 1964, The crystalline rocks of Howard and Montgomery Counties: *in* The Geology of Howard and Montgomery Counties: Maryland Geol. Survey, p. 27-215.

Jackson, C. T., 1853a, Report on the Dolly Hyde copper mine: Mining Mag., v. 1, no. 5, p. 476-480.

——, 1853b, Springfield copper mine: Mining Mag., v. 1, no. 6, p. 639.

Jonas, A. I., 1928, Map of Carroll County showing the geological formations: Maryland Geol. Survey.

Jonas, A. I., and Stose, G. W., 1938, Geologic map of Frederick County: Maryland Geol. Survey.

Jonas, A. I., Knopf, E. B., and others, 1925, Map of Baltimore County and Baltimore City showing the geological formations: Maryland Geol. Survey.

Knopf, E. B., and Jonas, A. I., 1929, The geology of the crystalline rocks of Baltimore County: Maryland Geol. Survey, Baltimore Co. Rept., p. 97-199.

Lesley, J. P., 1859, The iron manufacturer's guide to the furnaces, forges and rolling mills of the United States: New York, John Wiley, p. 50, 444.

Ludlum, J. C., 1955, Regional setting and mineralogic features of the Howell zinc prospect, Jefferson County, W. Va.: Econ. Geology, v. 50, no. 8, p. 855-861.

Martin, Thomas, and Vivian, R. W., 1865, Report of the New Burra copper mine, near Sykesville, Maryland, *in* Prospectus of the New Burra Copper Mining Company, New York, p. 7-8.

Maryland Geol. Survey, 1964, The Geology of Howard and Montgomery Counties: Maryland Geol. Survey, 359 p.

Mathews, E. B., and Grasty, J. S., 1909, Report on the limestones of Maryland, with special reference to their use in the manufacture of lime and cement: Maryland Geol. Survey, v. 8, p. 225-477.

Miller, B. L., 1941, Lehigh County, Pa. geology and geography: Pennsylvania 4th Geol. Survey, Bull. C39, p. 338-339.

Mining Magazine, 1853, Maryland copper, *in* Journal of copper mining operations: Mining Mag., v. 1, no. 1, p. 74.

——, 1854, Journal of copper mining operations: Mining Mag., v. 2, no. 6, p. 677.

Moore, H. C., 1935, A brief history of the copper mine at Bare Hills, Maryland: Maryland Nat. History Soc. Bull., v. 5, no. 9, p. 49-57.

New London Copper Mining Company of Frederick County, Md., 1864, Prospectus: Philadelphia, Pa.

Ostrander, C. W., and Price, W. E., Jr., 1940, Minerals of Maryland: Maryland Nat. History Soc., 92 p.

Overbeck, R. M., 1916, A metallographic study of the copper ores of Maryland: Econ. Geology, v. 11, no. 2, p. 151-178.

Pearre, N. C., 1964, Mining for copper and related minerals in Maryland: Maryland Historical Magazine, v. 59, no. 1, p. 15-33.

Piggot, A.S., 1858, The chemistry and metallurgy of copper: Philadelphia, Lindsay and Blakiston, p. 263-265.

Pumpelly, Raphael, 1886a, Geographical and geological distribution of the iron ores of the United States: U. S. 10th Census, v. 15, p. 3-36.

——, 1886b, Report on the mining industries of the U. S.: U. S. 10th Census, v. 15, p. xxxi, 798-799, 804, 977-978.

REMINGTON, EDWARD, 1852, A general report to the owners, respecting the Patapsco mines in Carroll County, Md.: Philadelphia, Pa., 16 p., 3 ill.

ROBINSON, R. J., 1939, Maryland's 200-year-old copper industry: Baltimore Md., p. 23-30.

SHANNON, E. V., 1923, Note on cobaltiferous gahnite from Md.: Am. Mineralogist, v. 8, no. 8, p. 147-148.

——, 1924, The present status of the mineral remingtonite: Am. Mineralogist, v. 9, no. 10, p. 208-209.

——, 1926, The identity of carrollite with linnaeite: Am. Jour. Sci., 5th ser., v. 11, p. 489-493.

SINGEWALD, J. T., JR., 1911, Report on the iron ores of Maryland: Maryland Geol. and Econ. Survey, Spec. Pub., v. 9, pt. 3, p. 308-319.

——, 1946, Mineral resources of Carroll and Frederick Counties: Maryland Dept. Geology, Mines and Water Resources, Carroll and Frederick Counties Rept., p. 132-162.

SMITH, J. L., AND BRUSH, G. J., 1853, Re-examination of American minerals: pt. 3, no. 28: Am. Jour. Sci., 2d ser., v. 16, p. 366-367.

STEVENS, H. J., 1900-1910, The copper handbook, vs. 1-10; Houghton, Michigan.

STOSE, A. J., AND STOSE, G. W., 1946, Geology of Carroll and Frederick Counties: Maryland Dept. Geology, Mines and Water Resources, Carroll and Frederick Counties Rept., p. 11-131.

TYSON, P. T., 1860, First report of the State Agricultural Chemist to the House of Delegates of Maryland, appendix, p. 15-17.

TYSON, P. T., 1862, Second report of the State Agricultural Chemist to the House of Delegates of Maryland: Annapolis, p. 64-70.

U. S. NINTH CENSUS, 1870, p. 762.

WATSON, T. L., AND GRASTY, J. S., 1916, Barite of the Appalachian States: Am. Inst. Mining Engineers Trans., v. 51, p. 530-532.

WEED, W. H., 1911, Copper deposits of the Appalachian States: U. S. Geol. Survey Bull. 455, p. 64-65.

WHITNEY, J. D., 1854, The metallic wealth of the United States: Philadelphia, Lippincott, Grambo & Co., p. 318-319.

WILLIAMS, G. H., 1886, The gabbros and associated hornblende rocks occurring in the neighborhood of Baltimore, Md.: U. S. Geol. Survey Bull. 28, 78 p.

——, 1891, Anglesite, cerussite and sulphur from the Mountain View Lead Mine near Union Bridge, Carroll County, Md.: Johns Hopkins Univ. Circ., v. 10, no. 87, p. 73-75.

——, 1892, Guide to Baltimore: Am. Inst. Mining Engineers, 139 p.

——, 1893, Mines and minerals, *in* Maryland, its resources, industries, and institutions, prepared for the Board of World's Fair (Chicago 1893) Managers, p. 112-114.

WILLIAMS, T. J. C., AND MCKINSEY, FOLGER, 1910, History of Frederick County, Maryland, v. 1, p. 275-277.

Subject Index

Author Index and Individuals Cited

EXPLANATION

Sykesville Formation
Heterogeneous group of boulder-bearing arenaceous to pelitic metamorphic rocks similar to gneissic granite

Peridotite
Rich in olivine, pyroxene, and magnetite; partly altered to serpentine

Talc schist
Contains numerous vugs from which siderite or ankerite has been dissolved

Chlorite-amphibole schist and gneiss
In part chlorite-rich, in part amphibole-rich. Locally contains altered plagioclase grains, talc, garnet, epidote and thin marble lenses. Includes sparse pegmatite stringers in northern band

Quartz-mica schist
Locally contains quartzite or quartz conglomerate bands; some garnet and chlorite are locally present, particularly in the southeast part of the area

PALEOZOIC(?)

▲
Bedrock outcrop used for lithologic but not structural data

70 — — ?
Contact showing dip
Dashed where location is approximate, queried where doubtfully located

— — — —
Probable fault or shear zone
Commonly mineralized with copper-iron-quartz veins

36
80

Strike of vertical foliation

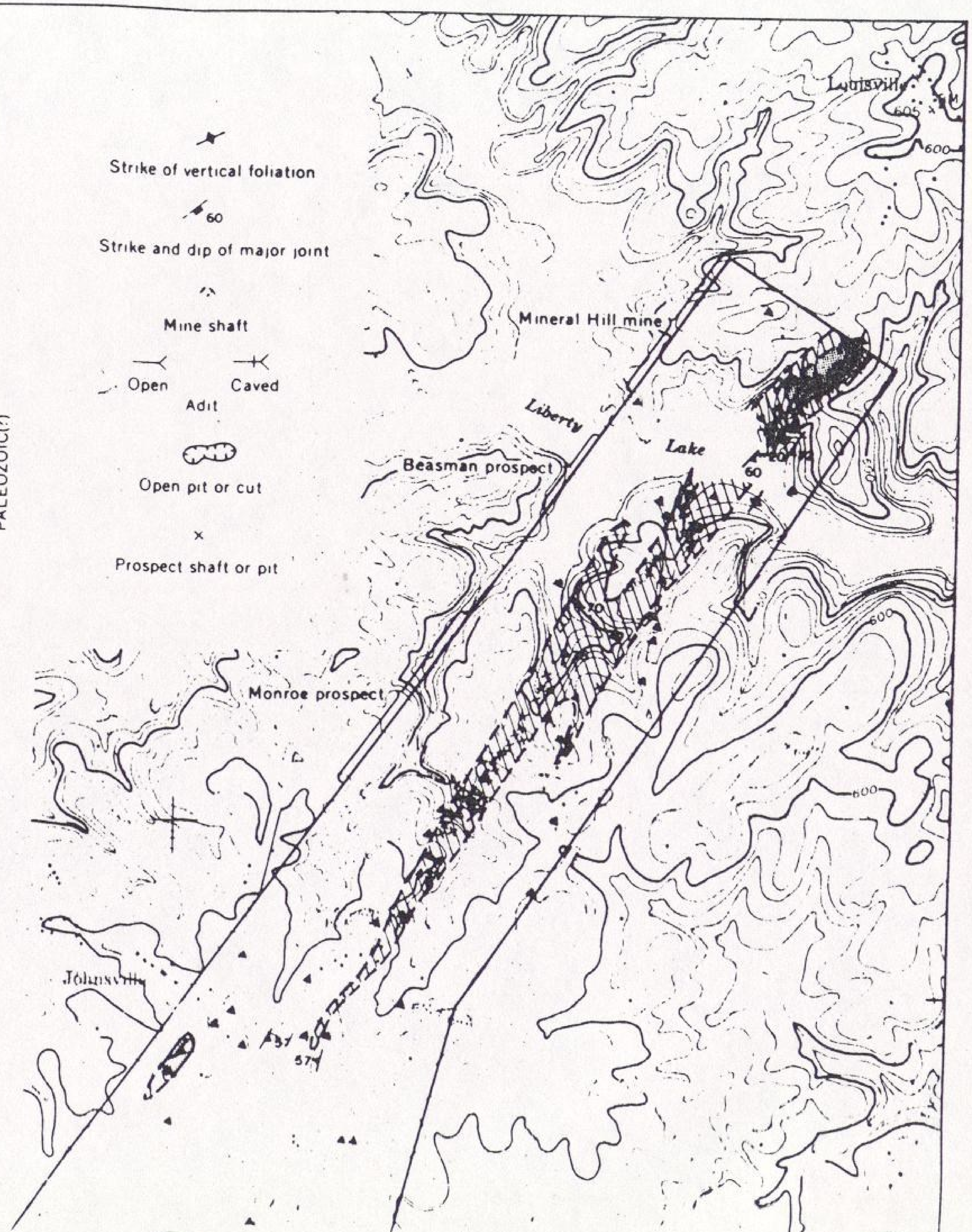
60
Strike and dip of major joint

Mine shaft

Open — Caved
Adit

Open pit or cut

×
Prospect shaft or pit



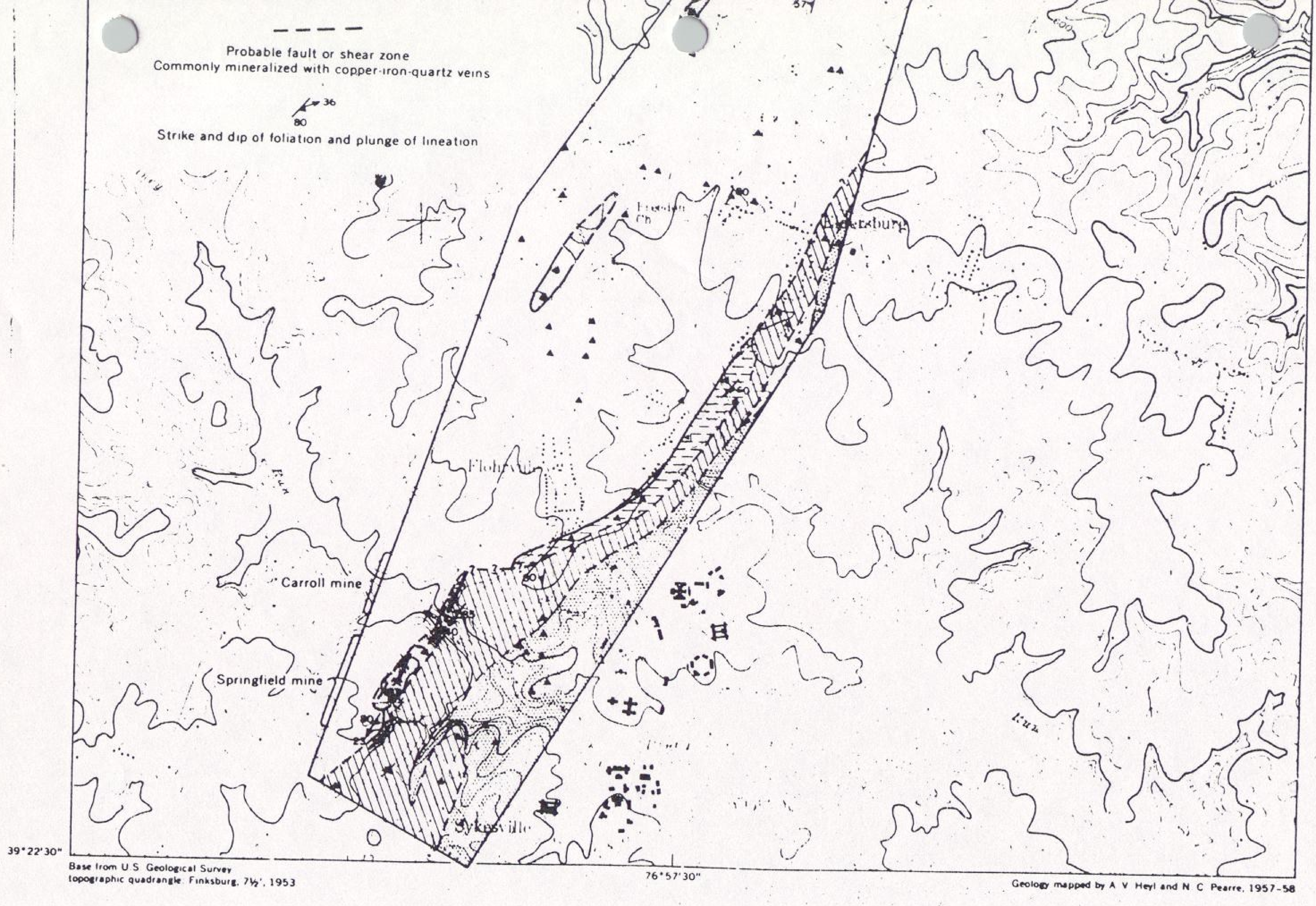
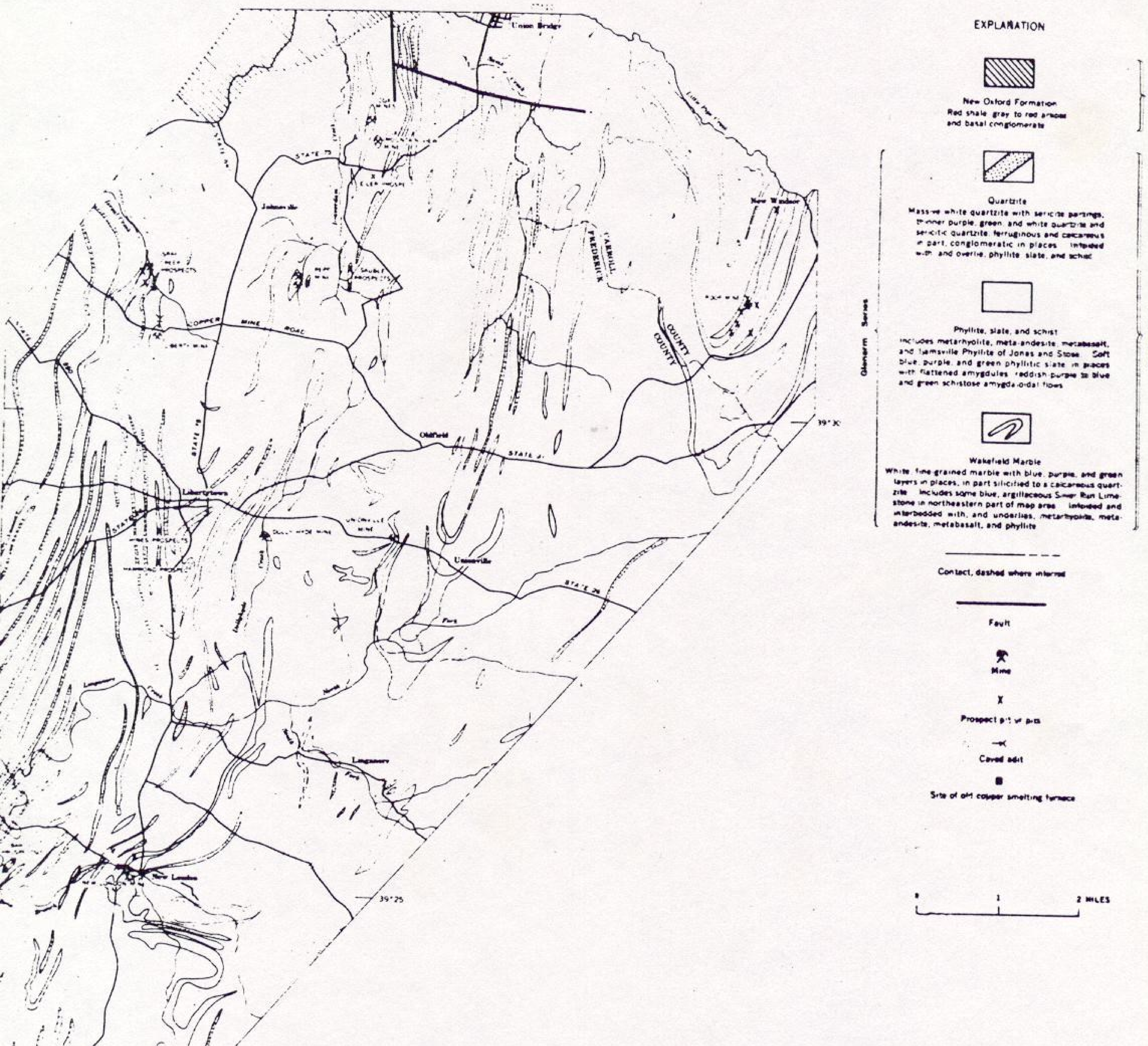


Figure 5. Geology and mines of the southern part of the Sykesville copper district, Carroll County, Md.



Geology and base from Jones and Stose (1938), compiled by N. C. Pearre, 1956

Figure 2. Geologic map of the Linganore district, Frederick and Carroll Counties, Maryland

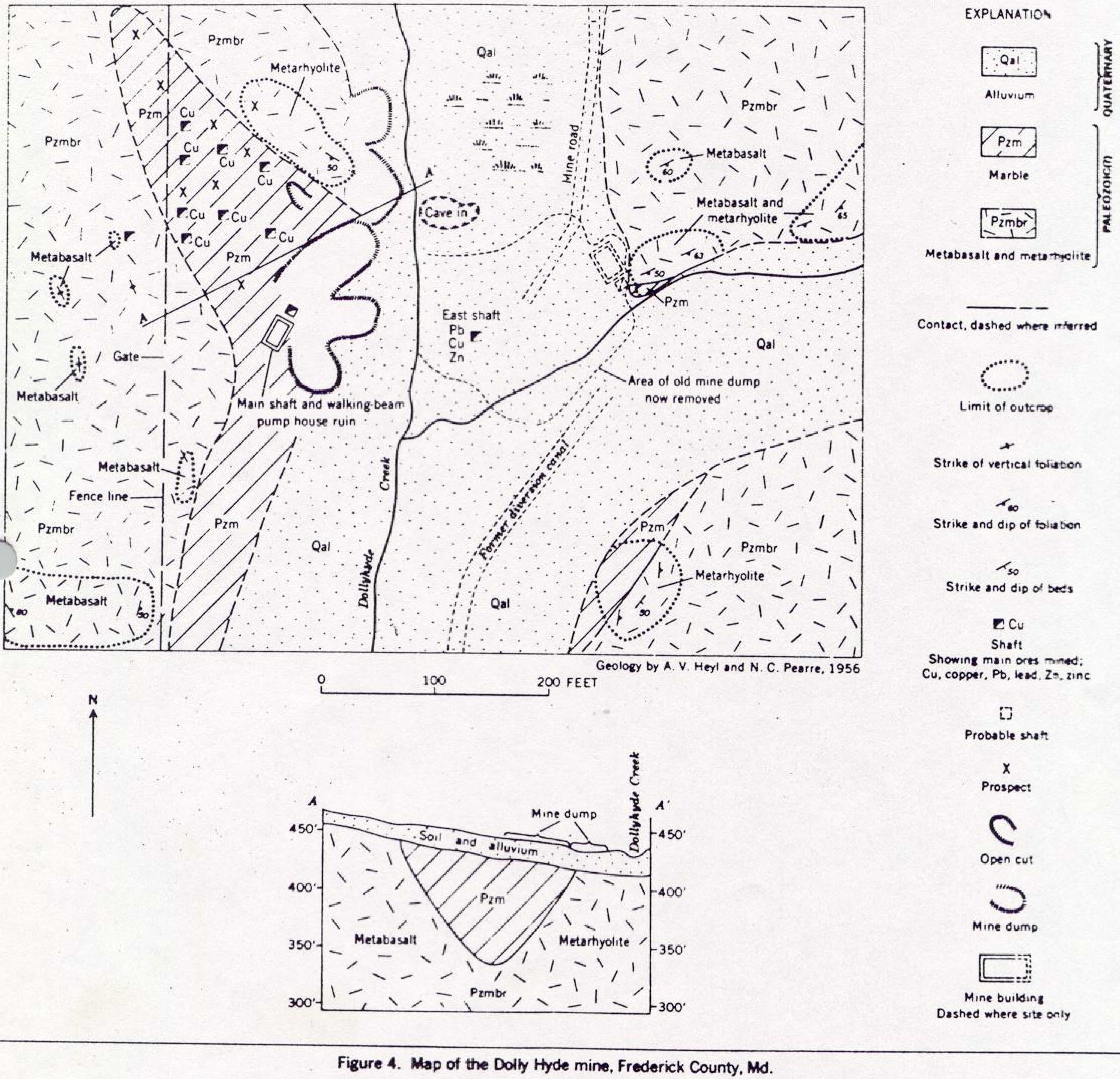
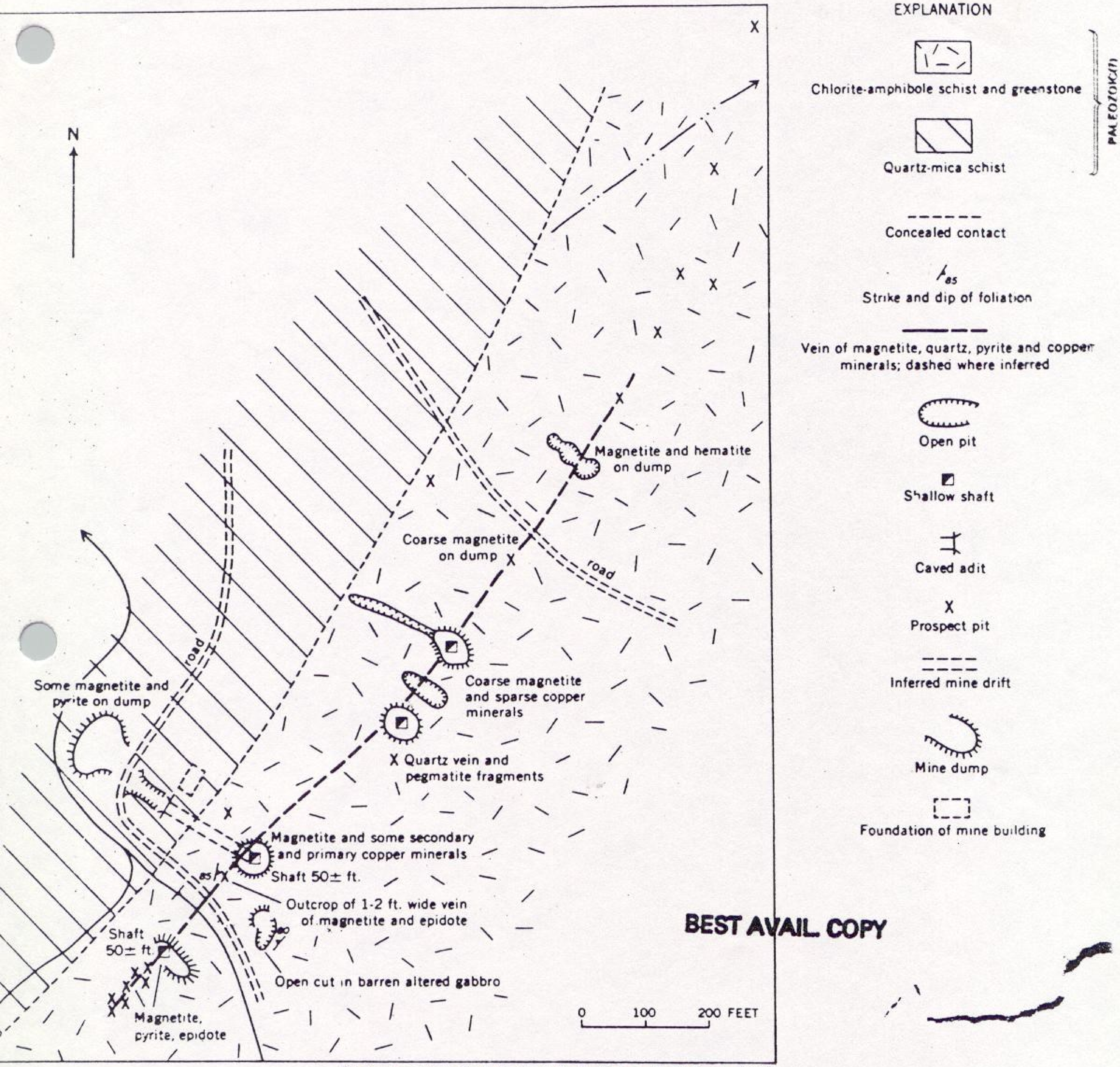


Figure 4. Map of the Dolly Hyde mine, Frederick County, Md.



Geology and base by A. V. Heyl, N. C. Pearre, M. R. Brock, 1957

Figure 6. Sketch map of Monroe prospect, Sykesville district, [illegible]roll County, Md.

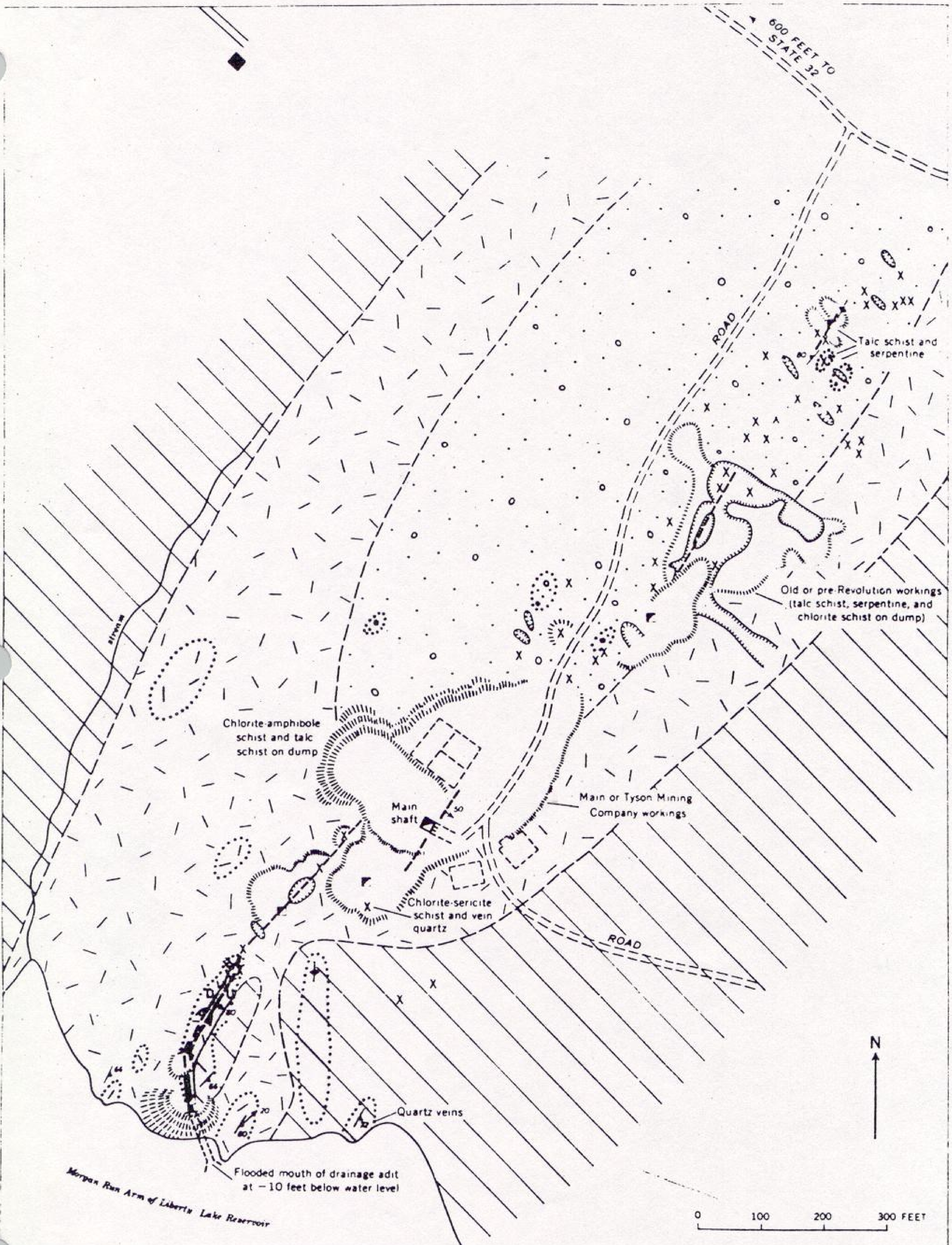
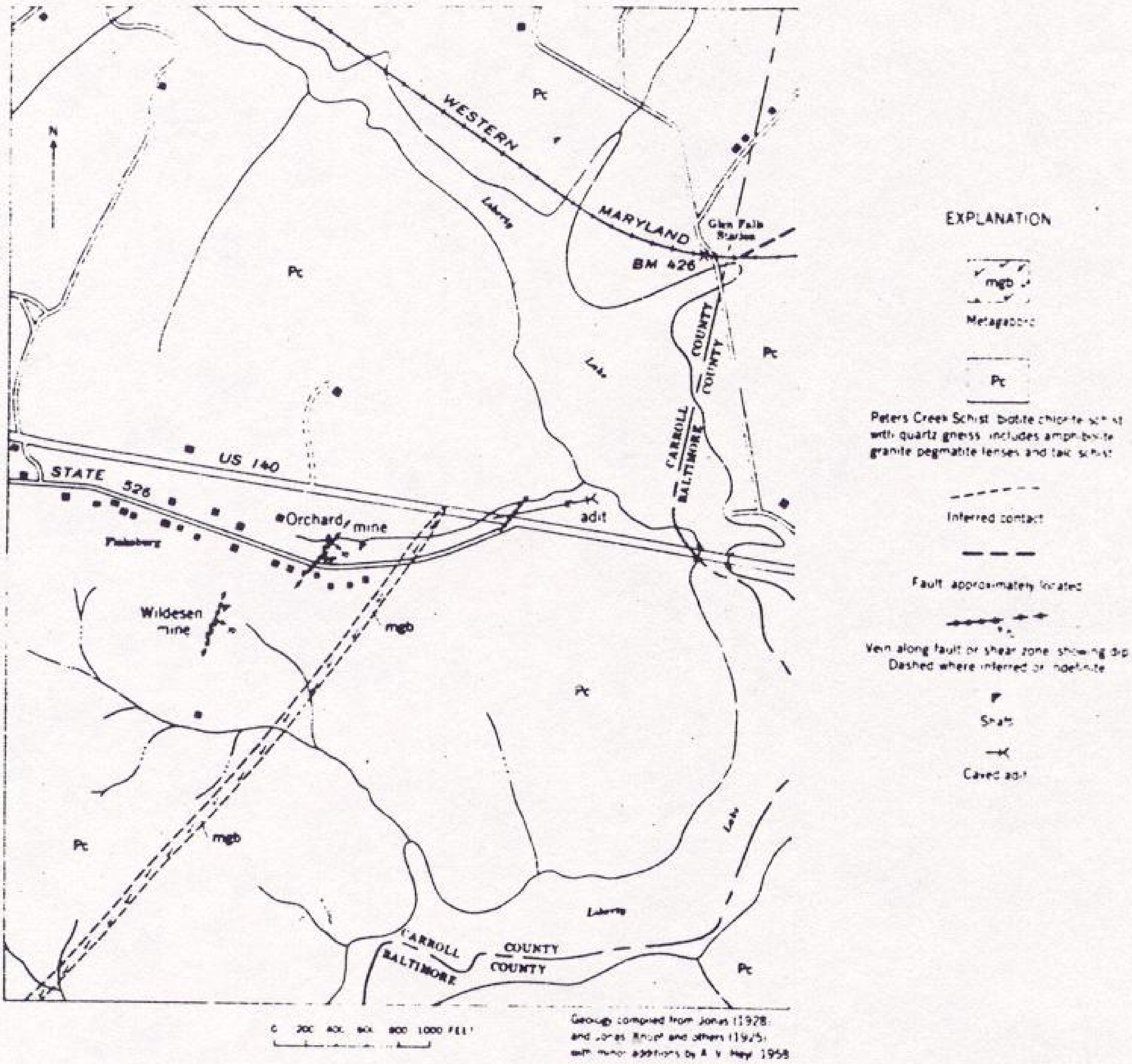


Figure 8. Map of Mineral Hill mine, Sykesville district, Carroll County, Md.

Geology and pace and compass base map by A. V. Heyl and N. C. Pearre, 1957



A

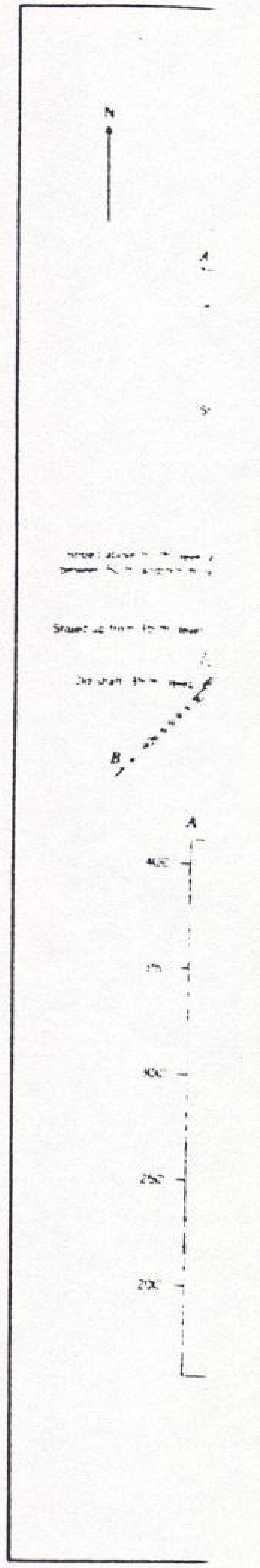
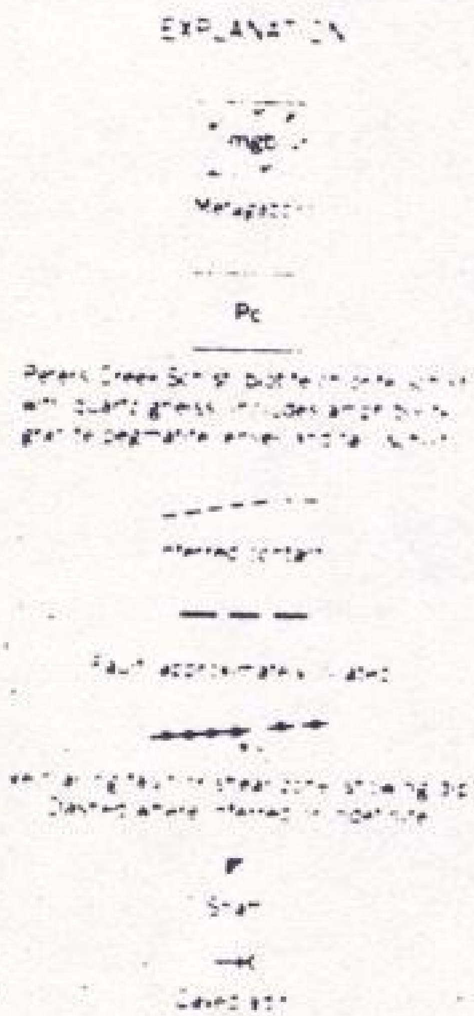
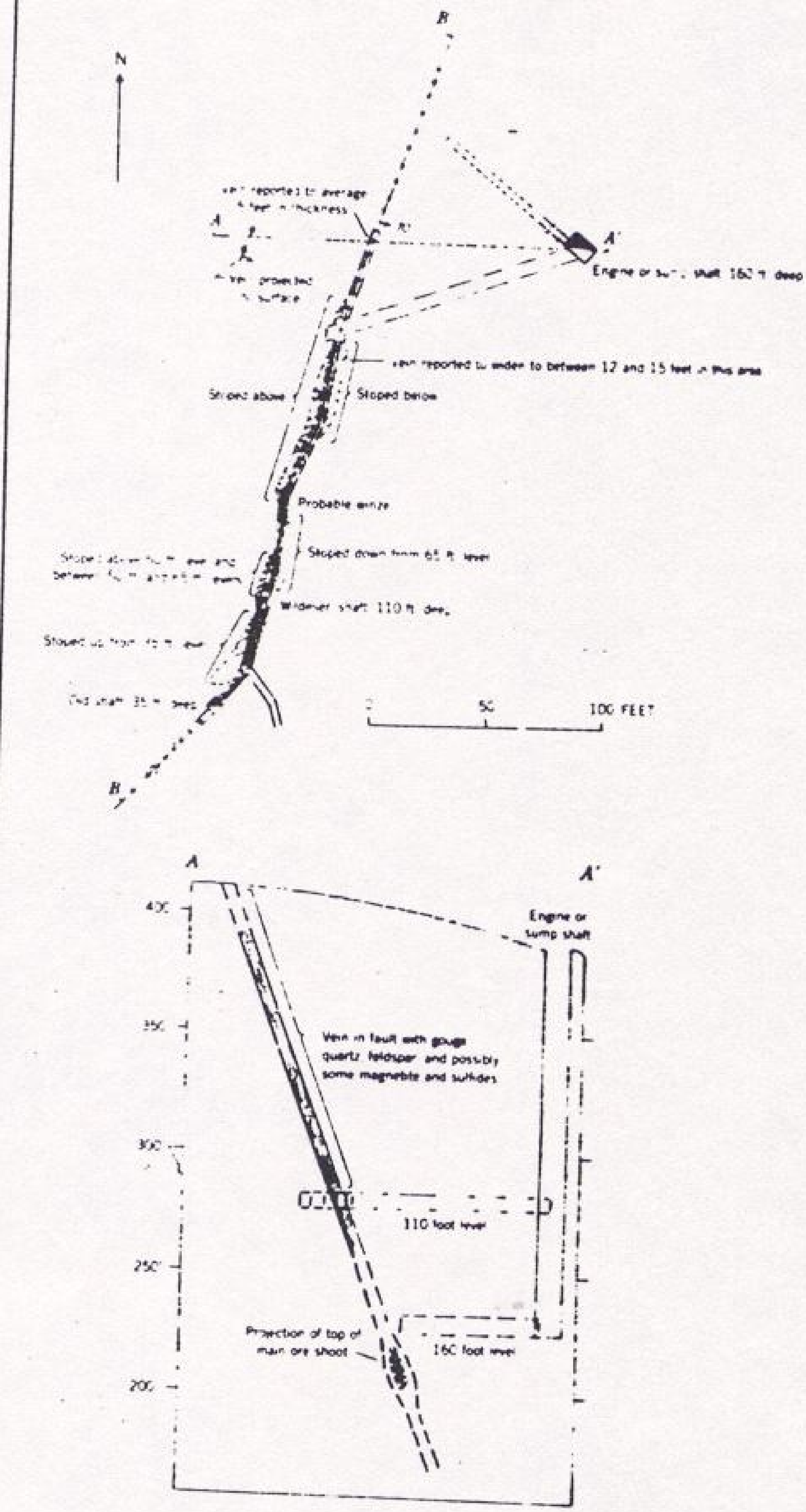
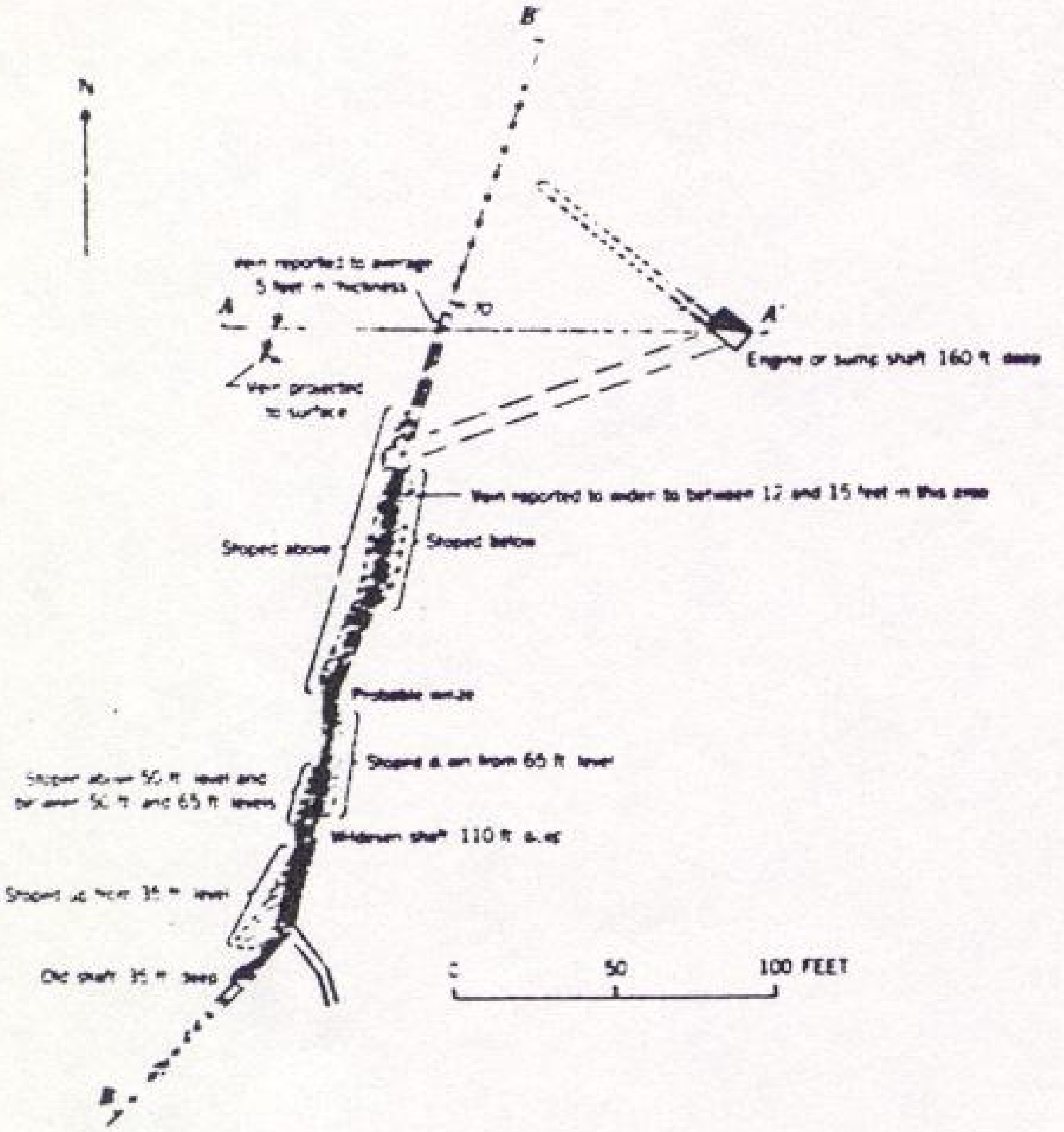


Figure 9. Geologic map of the Patapsco mines (A), and map and sections of the Wildesen mine (B), Sykesville district, Carroll and Baltimore Counties, Md.





sco mines
desen mine
altimore



EXPLANATION

IN PLAN

Vein showing dip, dashed where inferred. Line marks center of lenticular vein 5 to 15 feet wide

Shaft

Top of winze

Foot of inclined winze

Mine workings, 35-foot level
Short dashes where inferred

Mine workings, 50-foot level

Mine workings, 65-foot level

Mine workings, 110-foot level

Mine workings, 190-foot level
Dashed where inferred

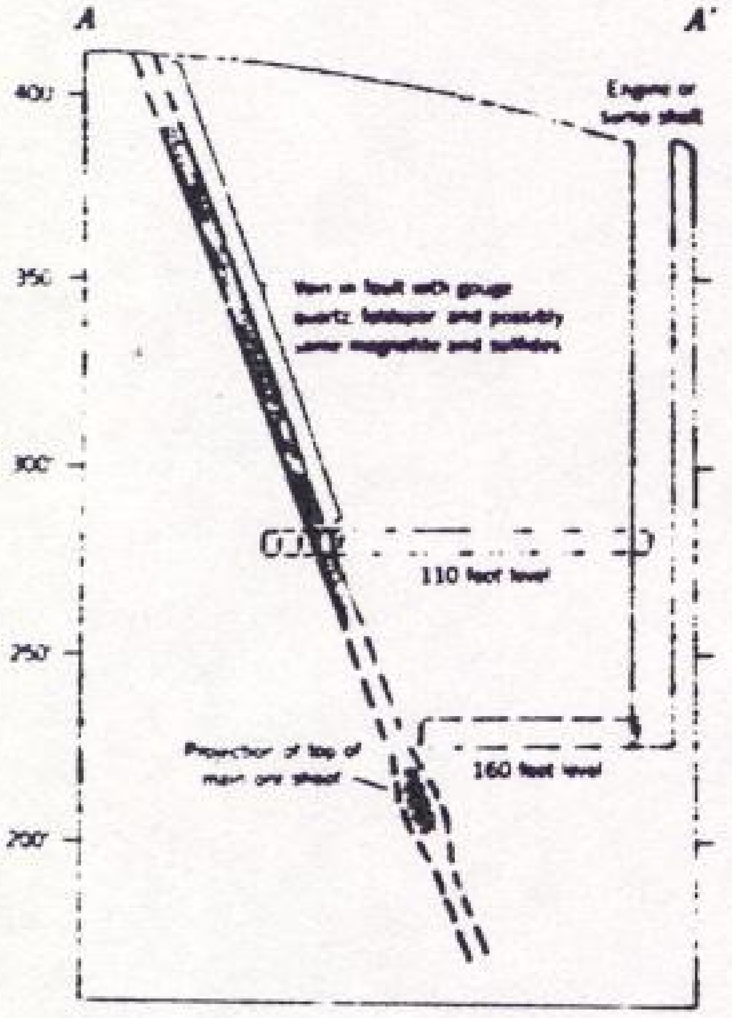
IN SECTIONS

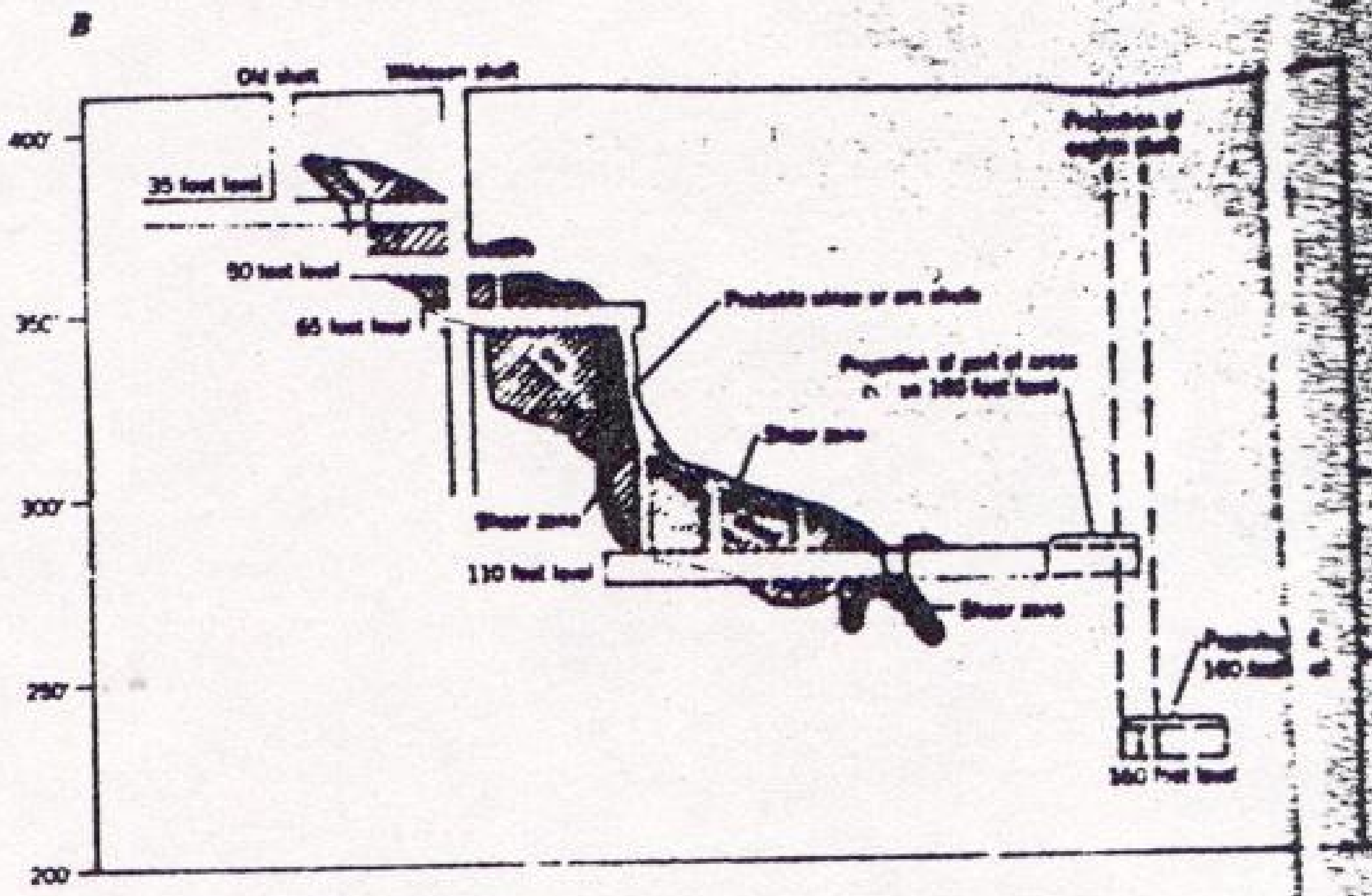
Mineralized vein or shear zone in fault with gouge, quartz, feldspar, dashed where projected. Inferred projection down plunge of top part of main ore shoot shown by cross-hatching in section A-A'

Stoped main ore shoot in section B-B'
Dotted line shows inferred margins in drifts

Mine workings and inferred mine workings
Dashed where projected

Stopes above and below drift





Exact orientation and position of some of the workings not known; they are plotted in their most probable relations. Datum is approximate sea level.

Compiled from Remington (1852) and field data

B

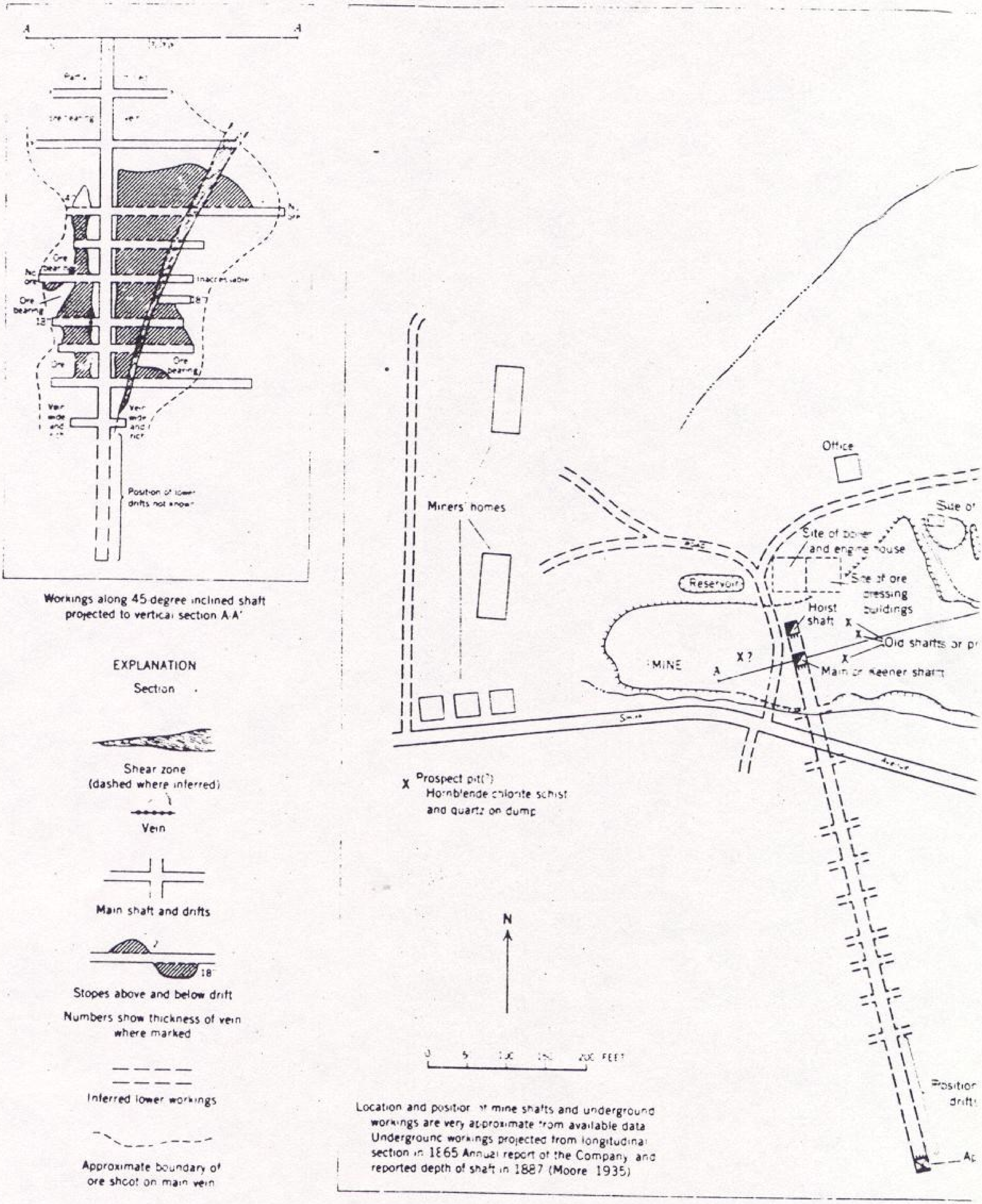


Figure 10. Map of Bare Hills copper

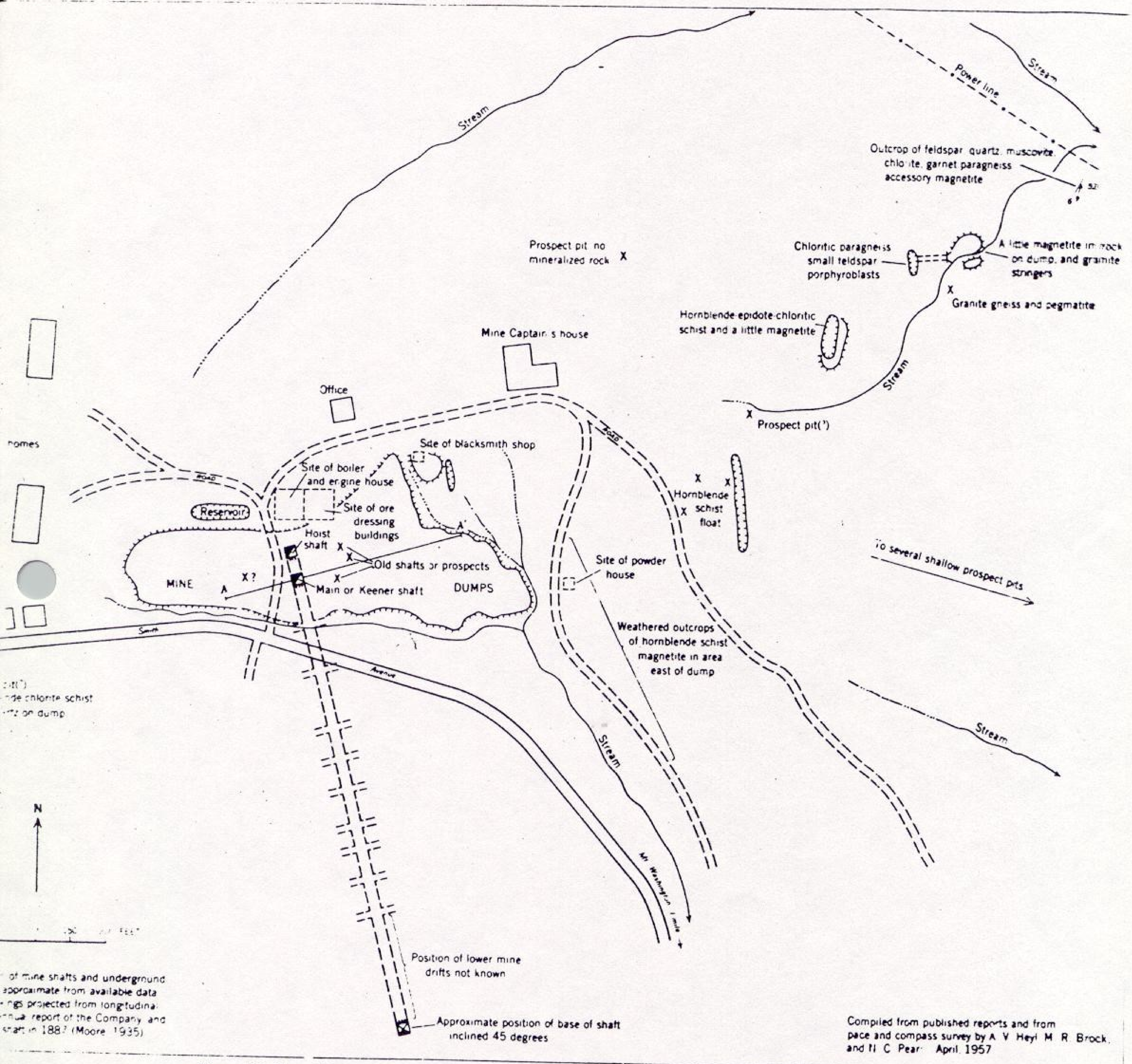


Figure 10. Map of Bare Hills copper mine and nearby prospects, Baltimore County, Md.